UNCOVERING THE MYSTERY:

AN APPLICATION OF XRF ON POSSIBLE COMINGLED REMAINS

A THESIS

SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE

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BY

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MASTER OF ANTHROPOLOGY

BY KATARINA WASLEY

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Dedications

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Chapter One: Introduction

Research Topic and Purpose

This research examines human remains from an African American tenant farmer cemetery in Lowndes County, Mississippi. The site (22LO998) is referred as either the Weyerhaeuser site or the Pepper Hill 1 Cemetery. The human remains at this site were discovered and salvaged during the early construction phase of a fire line at the Weyerhaeuser, Inc.'s Pulp and Paper Plant located near Columbus, Mississippi. The remains include seventeen burials. Previous analysis of the individuals indicated two possible adult males, one adult female, and several infants. A major problem that occurred with these remains was that they were disturbed by both the construction equipment at the site and the coroner that was called in to identify the skeletons as human (Hogue and Alvey 2006,1-6). The purpose of this thesis is to reconstruct the burials and reunite the disturbed skeletal elements to documented burials at the site.

The research involved several levels of inquiry. The first inquiry was to examine if the x-ray fluorescence methodology could positively distinguish two separate known skeletons located at Ball State University's Anthropology Department. The second line of inquiry focused on the Weyerhaeuser site remains. The first part of this inquiry was to attempt an identify potential matches amongst the dissociated remains and known burials by using bone morphology, measurements, and color. The second part of this inquiry examined if the use of x-ray fluorescence on the dissociated bones would produce reliable results to be placed with known burials. This research also involved a literature review of studies on other disturbed cemeteries, focusing on the methods that were used to reconstruct the disturbed burials.

The results of this research will aid in determining the number of individuals that the construction equipment and coroner may have disturbed and reunite several of the separated remains. First, an analysis of the burials and individual skeletal units was conducted using the methods outlined by Buikstra and Ubelaker (1994) to gather information about the bones. This reanalysis was followed by x-ray fluorescence analysis to determine the elemental composition levels of the skeletal components. The results of the x-ray fluorescence then underwent a discriminant function analysis that would compare the elemental composition levels to match the disturbed remains with the burials they belong.

Unfortunately, throughout United States history, some cemeteries have been neglected and forgotten only to be rediscovered, often through development related projects such as building roads and construction (e.g., Buzon et al. 2005; Stevens and Leader 2006; Watter 1994). In the case of the Pepper Hill 1 Cemetery site, according to a local source, the cemetery had been used until roughly 1956. It was at this point that the associated church, Pepper Hill MB Church, purchased land close to the church for a new cemetery that was used from 1956 to 1998. The church that was associated with these cemeteries closed in 2000 (Hogue and Alvey 2006, 5).

With the recent emergence of x-ray fluorescence in bioarchaeology (Byrnes and Bush 2016; Gonzalez-Rodriguez and Fowler 2013; Janos et al. 2011; Nganvongpanit et al. 2016a;

Perrone et al. 2014; Piga et al. 2014; Swanston et al. 2012), this technique is being explored to understand the various research avenues that are possible in the field, such as applications with human and faunal remains to determine answers for questions such as an individual/community diet, species identification, and reconstructing individual skeletons in commingled situations. The literature suggests that the method of x-ray fluorescence has been successful in determining the different individuals by focusing on select elemental composition levels (Byrnes and Bush 2016, Gonzalez-Rodriguez and Fowler 2013, Janos et al. 2011, Perrone et al. 2014). This thesis combines both traditional osteological analysis with x-ray fluorescence analysis to determine which disturbed bone elements belong to which individuals from the Pepper Hill 1 Cemetery.

Chapter Two: Weyerhaeuser Site (22LO998)

Pepper Hill 1 Cemetery

The discovery of the Pepper Hill 1 Cemetery in Lowndes County, Mississippi (Figure 1) occurred during the 2005 construction of a water-line ditch at the Weyerhaeuser's Pulp and Paper Plant. Construction for this site stopped once human remains were found on site. When the site became classified as a historic period cemetery on June 7, 2005, Weyerhaeuser, Inc. funded a project to have the remains excavated by S. Homes Hogue and Jeffery Alvey of the Cobb Institute of Archaeology at Mississippi State University. The fieldwork to recover the human remains began on June 27, 2005 (Hogue and Alvey 2006).

For the excavation of the remains at this site, various methodologies were used. Grids of 1 m^2 were put in place to help with excavation and mapping of the burials. Initially, five burials were discovered. All burials were photographed and drawn to scale before excavation began. In conjunction with excavation, a surface collection was conducted in order to recover any other skeletal material that may have been disturbed throughout the construction site. Before finishing the fieldwork for this site, a ¾" soil probe was used to detect if there were any other burials in the immediate construction site area as the discovered five burials. With this probe, it was concluded that there were no other burials in the immediate vicinity of the known burials (Hogue and Alvey 2006).

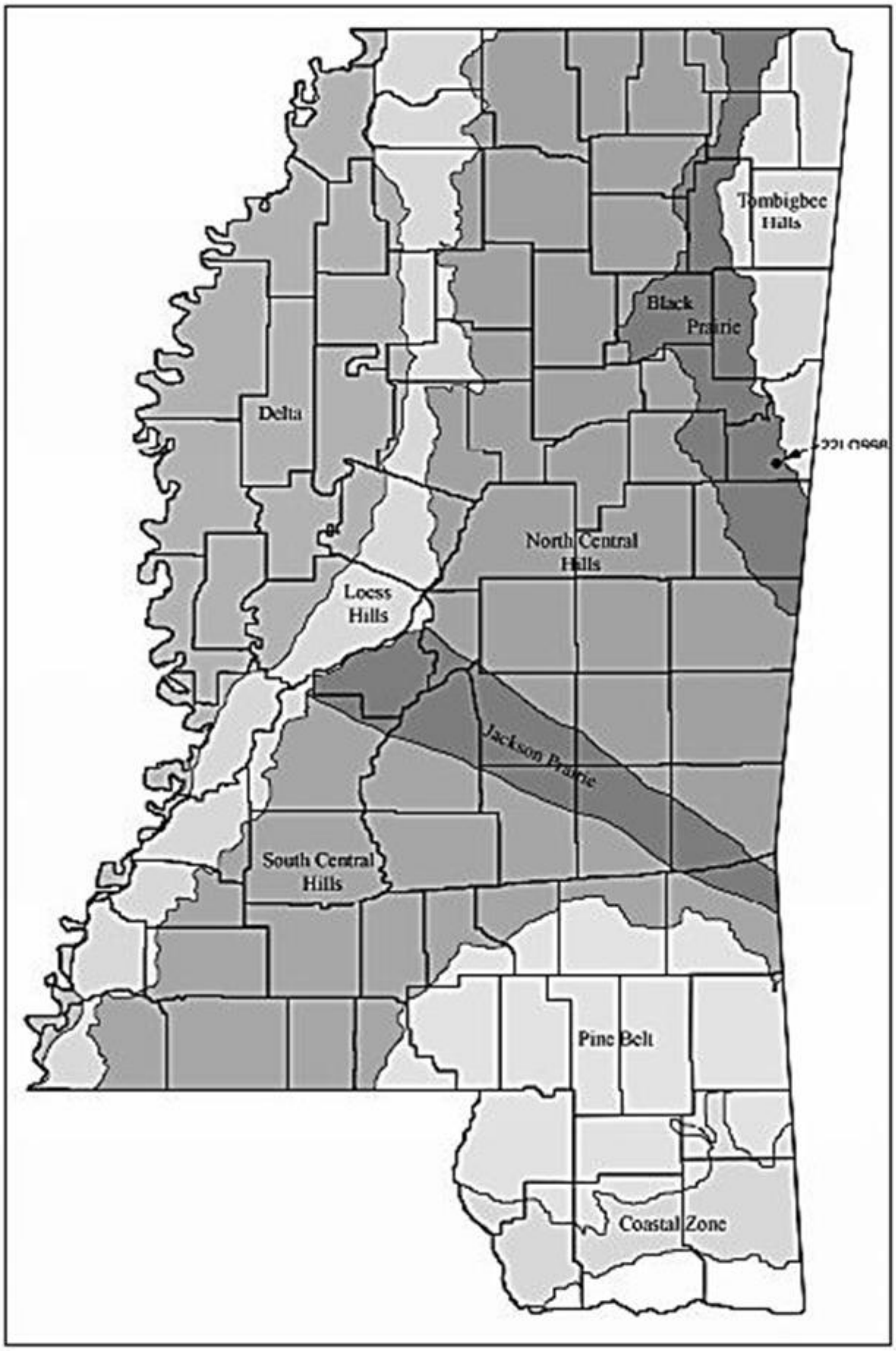


Figure 1. From Hogue and Alvey 2006

During the first round of fieldwork, there were five areas where individuals were found at the site. These were labeled Burials 1/3, 2, 4, 5, and 6. Initially, Burials 1 and 3 were considered separate individuals, but later was determined that they were the same burial and relabeled as Burial 1/3. Burials 2 through 6 had been found while *in situ* while Burial 1/3 was not. Also, a single femur was recovered close to Burial 5 and was labeled as Burial 5a. It was noted during the excavation that there was a variance in the strata levels. During the construction process, the area was brought down to a clay subsoil. About ten to twenty centimeters above the graves, there was a fill level that contained crushed asphalt. These strata differences suggest two possibilities: first, during the initial construction of the plant in the 1970's, it is possible that graves from this site were disturbed; and second, there may be more graves present at this site (Hogue and Alvey 2006).

Following this initial investigation, the bioarchaeologist gave two recommendations, with the Mississippi Department of Archives and History (MDAH) concurring, to the contractors at the site. The recommendations were to either determine the cemeteries borders and avoid any construction within these borders or continue construction and retain a bioarchaeologist on site in case more human remains were discovered. The contractors opted to retain a bioarchaeologist since construction needed to continue due to equipment needs (Hogue and Alvey 2006).

In early August 2005, more human remains were found at the construction site. An initial recommendation was given to leave the burials where they were located, but the Mississippi Department of Archive and History (MDAH) said that it would violate Mississippi

Law 97-29-25 as building on top of burials may be seen as a desecration of the human remains. From this, two recommendations were given by the bioarchaeologist, MDAH concurred again: locate the boundaries of the cemetery and avoid building on top of it or locate and remove all the graves before continuing construction. The company decided to have the graves removed, and fieldwork for this second project began on August 8, 2005 (Hogue and Alvey 2006).

The methods used for this fieldwork included a small excavator used to clear an area of 45 m^2. By using the small excavator, six-inch intervals were removed to help identify burial locations and potentially reduce the amount of damage to a burial. During fieldwork, Burials 7 through 16 and three additional features were identified. All human remains and artifacts were collected and analyzed at the Cobb Institute of Archaeology at Mississippi State University. It was during analysis that it was discovered that Feature 1 was a burial and hence relabeled as Burial 17. Fieldwork was completed on August 19, 2005, with a total of seventeen burials found and recovered at the Weyerhaeuser site (Hogue and Alvey 2006). Figure 2. From Hogue and Alvey 2006, provides a map of the locations of the burials.

The question remains as to why this cemetery had not been identified prior to construction. There was one individual who had come forward with some knowledge about the cemetery. This individual had previously been a member of a neighboring community and was able to give some history about the cemetery. The cemetery had been associated with a church, Pepper Hill MB Church, located roughly a mile and half northwest of the cemetery. While the individual was not able to give an exact start date for the use of the cemetery, they were able to recount that the cemetery was used from the late 1800s to 1956. The church had decided to purchase land across from the church in 1956 for the use of a new cemetery. This later dating cemetery was used from 1956 to 1998. When archaeologist Alvey went to investigate the claims, it was discovered that the church had closed in 2000. Fortunately, the headstone found in the cemetery located across from the church was able to support what the informant stated as eight headstones dated from 1956 to 1998 (Hogue and Alvey 2006).

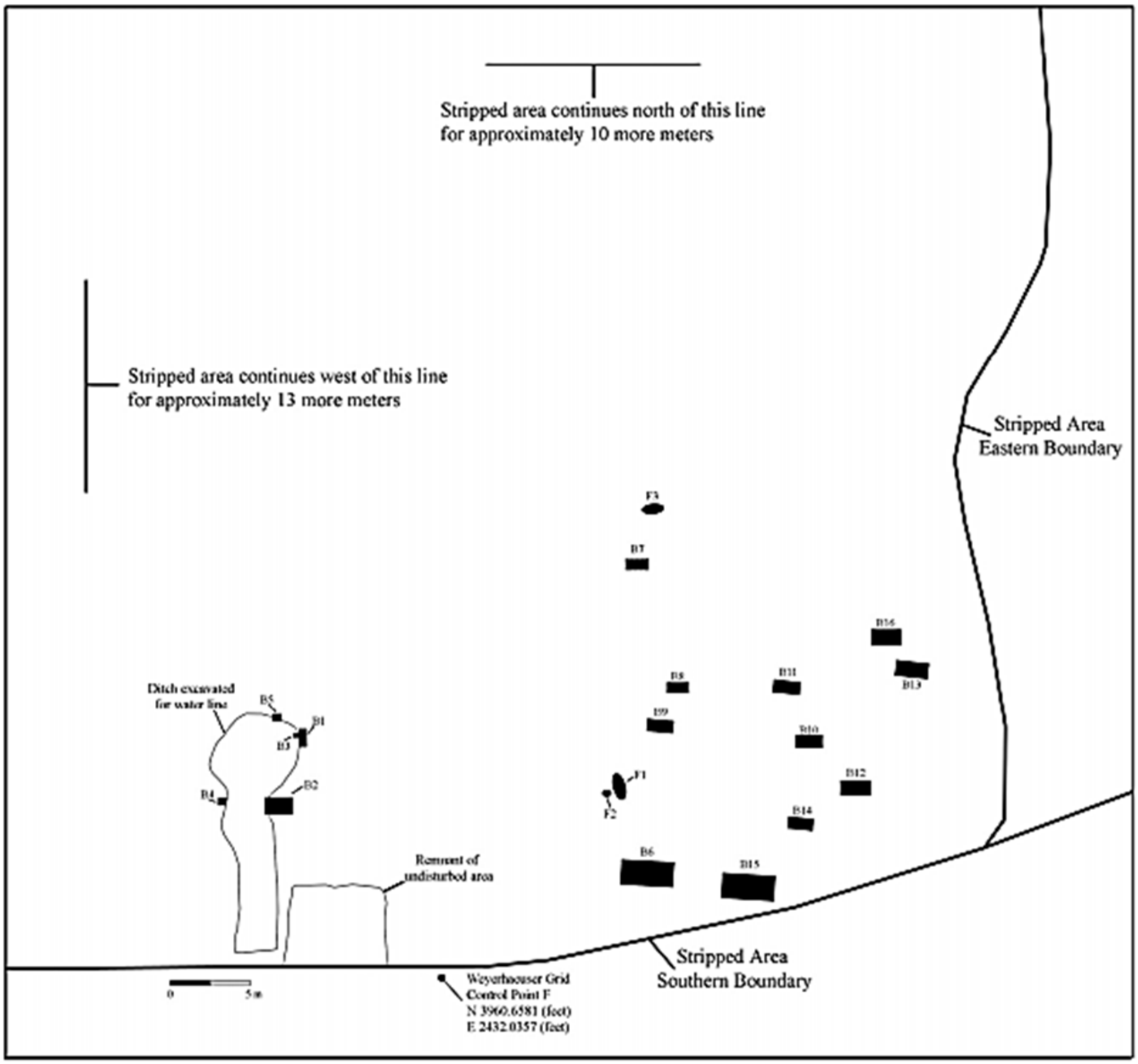


Figure 2. From Hogue and Alvey 2006

Chapter Three: Review of X-Ray Fluorescence and Commingled Human Remains

The literature on the use of x-ray fluorescence on human remains is limited due to the recent expansion of x-ray fluorescence into the fields of bioarchaeology and forensic anthropology. The earliest article found referencing x-ray fluorescence being used for analysis on human bone was from 1989 (White and Schwarcz 1989), though publications using x-ray fluorescence with bone as a test subject did not start appearing more often until the 2000's (Bush et al. 2007; Carvalho et al. 2000; Carvalho, Marques, and Brito 2003; Carvalho et al. 2004; Carvalho and Marques 2008; Piga et al. 2009; Schweitzer et al. 2005; Thomsen and Schatzlein 2002; Wittmers Jr. et al. 2008) with the bulk of the articles being published after 2011 (Abu Dalou et al. 2017; Byrnes and Bush 2016; Christensen, Smith, and Thomas 2012; Choudhury et al. 2016; Dias et al. 2015; Dolphin et al. 2013; Finlayson et al. 2017; Fowler and Thompson 2015; Giffin et al. 2017; Gilpin and Christensen 2015; Gonzalez-Rodriguez and Fowler 2013; Guimarães et al. 2016; János et al. 2011; Kuzel, Christensen, and Marvin 2016; Little et al. 2014; López-Costas, Lantes-Suárez, and Cortizas 2016; Olympus Corporation 2011; Pessanha et al. 2016; Piga et al. 2014; Perrone et al. 2014; Nganvongpanit et al. 2016a; Nganvongpanit et al. 2016b; Nganvongpanit et al. 2017; Swanston et al. 2012; Swanston et al. 2018; Winburn et al. 2017). Even though the literature is much more limited than related to other fields within archaeology, what is available in the literature contains valuable insights in various ways the method can be applied. The available literature helps with providing information that not only explains what x-ray fluorescence is and the way that it works, but also explains how to use x-ray fluorescence to distinguish individuals from each other (Byrnes and Bush 2016; Carvalho et al. 2004; Finlayson et al. 2017; Gonzalez-Rodriguez and Fowler 2013; López-Costas, Lantes-Suárez, and Cortizas 2016; Perrone et al. 2016; Piga et al. 2014; Nganvongpanit et al. 2016a; Nganvongpanit et al. 2016b; Nganvongpanit et al. 2017).

The x-ray fluorescence analyzer emits an x-ray beam into the bone that affects all the way to the atoms of individual elements found within. The x-ray beam knocks an electron from the inner shell out of place and leaves the atom's electrons scrabbling to fill that void that was just created. While an electron from one of the outer shells moves to fill this void, it emits what is called a "lower-energy secondary fluorescent x-ray" (Perrone et al. 2014: 146). This energy is also referred to as either a "K" line or a "K" shell. The opposite of this energy is the "L" line or the "L" shell which represents the energy signature of the atom that fills the spot of the atom that moved to the inner "K" shell (Perrone et al. 2014; Thomsen and Schatzlein 2002). The energy that is released from this movement indicates the element that's present. The energy signature, which is unique to an element, is then picked up by the x-ray fluorescence that then sends the data to be analyzed with computer software that will record the amount of that element, and any other element, that is in the sample (Christensen, Smith, and Thomas 2012; Finlayson et al. 2017; Perrone et al. 2014; Swanston et al. 2012; Thomsen and Schatzlein 2002; Winburn et al. 2017).

Depending on the type of x-ray fluorescence model that is used, the methodology can either be non-destructive or destructive. Due to the stationary nature of the design of some x-ray fluorescence machine models, samples may have to be reduced, for example like cutting or powdering, to fit within the testing area. One type of model, the portable x-ray fluorescence, which was used for this research project, allows for samples to remain completely intact and is capable of moving its testing area to fit the needs of the sample, even if the sample is still *in situ* (Byrnes and Bush 2016; Carvalho et al. 2000; Finlayson et al. 2017; Kuzel, Christensen, and Marvin 2016; Perrone et al. 2014; Swanston et al. 2012).

There are limitations to this method as x-ray fluorescence can only detect elements from fluorine (atomic number 9) to uranium (atomic number 92)(Christensen, Smith, and Thomas 2012; Perrone et al. 2014), though one article suggests that elements lighter than phosphorus could be read with the help of a vacuum hood to prevent the air from absorbing the elements (Byrnes and Bush 2016). It is mentioned in various articles that the preferred elements to use for analysis of skeletal remains are phosphorus, calcium, potassium, zinc, magnesium, iron, strontium, and lead due to these elements being most commonly detected and they hold other insights to a dietary, physiological, and biological significance to the individual (Fulton et al. 1986; Gonzalez-Rodriguez and Fowler 2013; Perrone et al. 2014). Though, depending on the experiment, only a few elements may be chosen to be used in the analysis of x-ray fluorescence —elements selected for testing depend on the type of data that a researcher may need to answer the questions that they propose and will not be the same in every experiment (Perrone et al. 2014).

Researchers note that, on average, about five to ten percent of bone is replaced by new bone every year in adults (Carvalho et al. 2004; Guimarães et al. 2016; Perrone et al. 2014). Due to this, new layers of bone have the possibility of producing different readings than those of the older layers of bone. Cortical bone is better for testing for two main reasons. The first corresponds with layers of the bones; the layers of cortical bone take longer to remodel completely, which represent a more substantial portion of an individual's life. The second reason is that due to the non-porous nature of the surface of the cortical bone, it makes it ideal for analysis because there is less of a chance of contamination (Byrnes and Bush 2016; Carvalho and Marques 2008; Guimarães et al. 2016; Janos et al. 2011).

Other influences that affect the results of the bones' results are the environment, dietary habits, and other factors that can account for variability of the skeletal makeup to help distinguish individuals (Carvalho et al. 2004; Carvalho and Marques 2008; Guimarães et al. 2016; Janos et al. 2011; López-Costas, Lantes-Suárez, and Cortizas 2016; Perrone et al. 2014; Piga et al. 2014; Swanston et al. 2012). Byrnes and Bush (2016), Carvalho et al. (2004), Carvalho and Marques (2008), Christensen, Smith, and Thomas (2012), Guimarães et al. (2016), López-Costas, Lantes-Suárez, and Cortizas (2016), and Janos et al. (2011) also bring to light that multiple diagenesis changes can occur to the bones after interment. Types of diagenetic factors that can change the elemental composition of the bone include precipitation, mineral replacement, absorption, dissolution, and recrystallization (Carvalho et al. 2004: 1252; Carvalho and Marques 2008: 32). An example of this is that the soil surrounding bones can either potentially leach elements from the bones or have elements from the soil absorbed by the bone. Elements that have been noted for being leached are iron, chlorine, strontium, and manganese (Byrnes and Bush 2016, Janos et al. 2011).

As mentioned earlier, the use of x-ray fluorescence in the bioarchaeological and forensic anthropology fields is relatively new, considering how long this method has been used in archaeology. Some of the ways that this method helps with bioarchaeology is to determine trace amount of elements in bones, assist with determining the provenance of the bone, helpful in determining the elemental levels of bones of different ages, and with studying the way different diagenetic processes affect the bone. In forensic anthropology, x-ray fluorescence helps with individual's identification with cases of cremation (Bush et al. 2007; Gilpin and Christensen 2015), determining trace evidence (Byrnes and Bush 2016; Carvalho et al. 2004; Carvalho and Marques 2008; Schweitzer et al. 2005), and the distinguishing of human and nonhuman bones (Nganvongpanit et al. 2016a; Nganvongpanit et al. 2017). In all cases, the method helps in distinguishing which bones belong to which individual, the different environmental factors they may have been exposed to, possible occupations, diseases, socioeconomic status, the type of diet they had, and the possible location of where they lived (Abu Dalou et al. 2017; Fowler and Thompson 2015; Byrnes and Bush 2016; Carvalho et al. 2000; Carvalho et al. 2004; Carvalho and Marques 2008; Christensen, Smith, and Thomas 2012; Dolphin et al. 2013; Gonzalez-Rodrigeuz and Fowler 2013; Guimarães et al. 2016; Little et al. 2014; López-Costas, Lantes-Suárez, and Cortizas 2016; Nganvongpanit et al. 2016a; Nganvongpanit et al. 2017; Perrone et al. 2014; Piga et al. 2014; Schweitzer et al. 2005; Swanston et al. 2012; Winburn et al . 2017; Wittmers Jr. et al. 2008).

There are applications of x-ray fluorescence that are still being explored. For one instance, Nganvongpanit et al. (2016b) have begun to examine if it is possible to determine whether x-ray fluorescence can be used to determine the sex of an individual. Though their initial experiment was not an overall success, they plan to examine different combinations of elements to determine whether or not this application of x-ray fluorescence will work (Nganvongpanit et al. 2016b). Another application that is being examined and needs further work is looking at cremation contaminations. Gilpin and Christensen (2015) have begun to explore the extent that x-ray fluorescence can be used in this area and have found that at this point that cannot provide a ratio of human ashes versus non-human contaminates in cremated remains, but x-ray fluorescence can tell if there is any non-human contaminates in the sample provided (Gilpin and Christensen 2015).

Experiments Using X-Ray Fluorescence

Chico Human Identification Lab Experiment

To test the x-ray fluorescence method, Perrone et al. (2014) designed an experiment that used 20 human adult remains from the Chico Human Identification Lab. The focus of this experiment was to create a small case of commingled remains to test the ability of the x-ray fluorescence as well to look at the inter- and intra- skeletal difference between skeletons (Perrone et al. 2014).

Their design was to test ten bones and one tooth from every individual if the bones were available. The bones that they chose to use were molar, the mental eminence of the mandible, 4th rib, 5th lumbar vertebrae, humerus, ulna, radius, femur, tibia, fibula, and a metacarpal. All bones were taken from the left side unless missing; then the right side was used. Before any bone was tested with the x-ray fluorescence, they were cleaned with 100 percent ethanol that was then allowed to air dry to avoid contaminations to the bone's surface (Perrone et al. 2014).

For the testing portion of the experiment, they applied the x-ray fluorescence for 180 seconds on the flattest portion of the bone. The model of x-ray fluorescence used in this experiment was the Bruker Tracer IV Series pXRF machine. The accompanying software used was the S 1 PXRF software version 3.8.30. Each sample was then scanned for 180 seconds on a power level of 15kV (Perrone et al. 2014)

The conclusion of this experiment provides a variety of results. First, it showed that x-ray fluorescence was capable of differentiating individuals with at least 15 different elements. The elements that were detected were sodium, magnesium, silicon, phosphorus, potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, and zinc (Perrone et al. 2014).

Perrone et al. (2014) stated that there should be little to no variance within an individual skeleton. When reviewing the data, they discovered an issue with the mercury data with the fifth lumbar and ulna that showed a significant difference between the detected levels in the bones. Though, when the researchers investigated further and removed the lumbar data, they found that there was no longer intraskeletal variance. While there was no variance intraskeletal, they did find inter-skeletal variances. Of the fifteen chemical elements looked at, fourteen chemical elements showed a variance that could prove helpful to distinguish separate skeletons. The one element, sodium, found that the concentrations were not very different between different skeletons (Perrone et al. 2014).

St. Katherine's Priory Experiment

Gonzalez-Rodriguez and Fowler (2013) introduce the limitation that x-ray fluorescence has when working to identify individuals. In their study, they used five adult human remains, four male and one female, that were recovered from a medieval burial site dated around mid-12th to early 16th century in Lincoln, United Kingdom. This burial site is associated with St. Katherine's Priory that also had a mixed Gilbertine order. The goal of this research is to look at the number of individuals that could be tested against each other to determine whom a skeletal element belonged to (Gonzalez-Rodrigeuz and Fowler 2013).

For the study, the researchers took twenty-three bones from each of the individuals. The bones that they used were the frontal bone, ramus of the mandible, scapulae, clavicle, two ribs, four vertebrae, sacrum, ilium, metacarpal, femur, and tibia. The researchers used both sides of paired elements where applicable. The researchers also noted that the ribs would be tested in three different spots to create an average of the three for the final measurement then. Before the experiment was conducted, the bones were washed with water using small brushes and left to air dry. It was noted that in this experiment the researchers used the XRF Niton XL3t Spectrometer Analyzer from Thermo Scientific (Gonzalez-Rodrigeuz and Fowler 2013).

The elements that were chosen to use for analysis in this study were lead, strontium, zinc, iron, calcium, and potassium. The researchers noted that each of these elements have reasons to be examined. Both strontium and lead are known to replace calcium. Strontium and zinc are linked with an individual's diet, though the zinc link is not entirely accepted. Then iron and potassium are more likely to be associated with blood over bone. While the researchers noted the reason for why they choose these elements, but they also stated that they did not take into account any diagenetic changes that may have occurred over time (Gonzalez-Rodrigeuz and Fowler 2013).

From this study, they were able to find that up to three individuals' data could be compared at the same time and receive clear separation on which individual the skeletal element did or did not belong. When testing four individuals, they found that two of the skeletons had 95.6 percent accuracy, and the other two skeletons had 82.6 percent correct classification. In the last test that the researchers ran, they tested all five skeletons at the same time. The following represents the correct classification percentages in the last test: 1st skeleton 95.6 percent, 2nd skeleton 78.3 percent, 3rd skeleton 73.9 percent, 4th skeleton 69.7 percent, and 5th skeleton 52.5 percent. The results of this study show that the more individuals tested against each other at the same time, reduced the ability to receive accurate results (Gonzalez-Rodriguez and Fowler 2013).

Queen Blanche and King Peter Experiment

In Piga et al. (2014) study, they are examining two individuals to look for possible internment or postmortem contaminations. The two individuals that are being tested are King Peter of Aragon and Queen Blanche of Anjou. These two individuals, plus another, were exhumed in March 2010 for the restoration of the burial sites and to conduct non-destructive research on the remains.

Before discussing the study on these two individuals, it is essential to know how each was interred. King Peter of Aragon had died on November 11th, 1285. He was buried in front of an altar at Royal Monastery of Santa Maria de Santes Creus. In early December 1302, the remains were moved into a final burial in a porphyry basin in a tomb. The conditions of the remains were excellent minus the feet being placed between the legs. Queen Blanche of Anjou died on October 14, 1310. History indicates that the original grave of Queen Blanche was desecrated in 1836. When exhuming the remains of the tomb in 1836, there were remains of three adults discovered. The remains that the laboratory determined to be Queen Blanche was a young women approximately 150 centimeters (Piga et al. 2014).

For the study, a handful of bones were chosen from each individual for research. For King Peter, an unknown number of rib and femur fragments were chosen while for Queen Blanche metacarpal, rib, and femur fragments were picked. The machine that the researchers used was a Bruker M4 Tornado μ-XRF Spectrometer at power level 50 kV as well as an unknown portable x-ray fluorescence spectrometry model at a power level of 40 kV (Piga et al. 2014).

The data that was gathered showed that there were very evident amounts of phosphorus and calcium along with lesser amounts of chromium, sulfur, magnesium, aluminum, titanium, chlorine, lead, potassium, manganese, iron, zinc, and strontium. With these elements, the researchers determined that the contamination either occurred during life or sometime after they died. Some of the hypotheses that may contribute to contaminations after death include the internment process that was chosen for the individual or, in the case of Queen Blanche, during the desecration of the burial site. Some of the elements that are associated with these hypotheses are potassium, sodium, chlorine, aluminum, and sulfur. The opposite side of this is the hypotheses that are associated with contamination during life. These hypotheses include what the individuals ate or drank during life or from some of the element that would have been found in some of the different cookware of the times (Piga et al. 2014).

Northern California Large Animal Scavenger Study

In Northern California, skeletal remains were recovered from a site of an illegal marijuana operation that led to homicide. Law enforcement that recovered the remains noted that the remains had been heavily scavenged by presumably large animals in the area. A barcode was assigned to each bone element or groups of articulated bones before the remains were sent to the Human Identification Laboratory at California State University, Chico to complete an analysis of the bones and to figure out the commingling situation (Finlayson et al. 2017).

Before the researchers went ahead with the use of the portable x-ray fluorescence, they went through six other methodologies. These include reconstruction of bone fragments, looking at the articulation of bones at joints, pairing bones based on visual assessments, using osteometrics to find matches, and having DNA samples sent to the California Department of Justice DNA Laboratory. The bones that went on for further testing with the portable x-ray fluorescence were the left scapula, left clavicle, left radius, left ulna, right 3rd metacarpal, right navicular, and the right first metatarsal (Finlayson et al. 2017).

The methodology that the researchers decided upon was to test each bone ten times with the portable x-ray fluorescence. The researchers then took the ten areas that were tested, isolated those areas, and then grounded the areas into powder to test. This was done so the results of the whole bones and powdered bone could be compared to see which would produce more accurate results. The machine that they used was a Bruker Tracer IV Series XRF unit. Each run was for 180 seconds with a power level at 1kV to 15kV (Finlayson et al. 2017).

The elements that the researchers recorded were silicon, phosphorus, potassium, calcium, manganese, iron, and cobalt. From the results between the whole bone and powered bone, there was a visible difference between the results, except in the case of cobalt. The variations between the two data sets were all less than three percent while in the case of iron, the variation was sixty-four percent. The result from this portion of the study was that whole bone testing is preferred over powered bone testing (Finlayson et al. 2017).

Regarding the commingling, the researchers decided that the best element to use was phosphorus. What they found from the results with portable x-ray fluorescence and the other methodologies was that all but two mandible fragments that belong to individual #1. From the analysis, the researchers found that individual #1 that was a Hispanic male between the ages of twenty to twenty-nine and was roughly 5’8.5” +/- 4”. From the two mandible fragments, the researchers concluded that individual #2 was probably a male over eighteen years of age of either White or Hispanic ethnicity (Finlayson et al. 2017).

Camp Jefferson Davis Study

In 1979, a fisherman found two coffins eroding on a beach on Greenwood Island near Pascagoula, Mississippi. The area that these coffins were found was part of the cemetery for Camp Jefferson Davis. This camp had been established during the Mexican-American War in 1848 and was used as either a pit stop for soldiers being deployed to the newly defined United States and Mexican border or as a hospital for soldiers too ill to go home. The two remains that found were analyzed and later reinterred with military honors at Biloxi National Cemetery in 1989. In 2008, a fisherman again found three remains in the Camp Jefferson Davis cemetery area (Olympus Corporation 2011).

Archaeologists were called to the site where they excavated the remains and performed skeletal analyses. During the analyses, they found a metallic substance on one of the right clavicles. They determined that the metallic material was an accretion on the bone rather than embedded in the bone as they had previously thought. The research had two hypotheses of what this mysterious metallic substance was. Either it was a bullet, which they believe was unlikely due to the lack of damage on the clavicle, or that it from a pewter button (Olympus Corporation 2011).

To determine which of these hypotheses was correct, the researchers employed the use of x-ray fluorescence. They tested two areas on the bone: the metallic substance and the shaft of the right clavicle. The x-ray fluorescence results of the metallic substance showed that there was a high level of lead and moderate levels of tin whereas the shaft of the clavicle had an extremely low level of lead and virtually no trace of tin. To test against these results, two pewter buttons from the burials were tested. The researchers found that the average ratio of lead and tin in the pewter buttons was 1.62 to 1.00, while the mysterious metallic substance had a ratio of 16.70 to 1.00 (Olympus Corporation 2011).

Due to these results, the researchers could determine that the metallic substance did not come from a pewter button. Instead, they came up with two possibilities. The first possibility is that the metallic substance is from a bullet due to similar ratio consistency. The other possibility is that the substance is from coffin hardware, although there was no hardware recovered from either the 1979 or 2008 excavations to test (Olympus Corporation 2011).

Preliminary Species Identification Study

In bioarchaeology and forensic anthropology, the question of whether osteological material is human or non-human is essential. Nganvongpanit et al. (2016a) conducted a study to determine if it was possible to differentiate between human and non-human remains by using x-ray fluorescence.

The study looked at four species belonging to three different categories. The first category is the long-living mammals that include humans and Asian Elephants. The second category is a short living mammal represented by dogs, while the third category is marine mammal represented by spinner dolphins (Nganvongpanit et al. 2016a).

For testing, the researchers selected bones from each species. They selected six Thai female remains and chose the humeri, tibias, radii, ulnas, ribs, femurs, fibulas, and metatarsals to test. Two female Asian elephants were selected and choose humeri, ulnas, radii, ribs, femurs, tibias, and fibulas for testing. Ten female dogs were selected with the craniums, mandibles, ribs, cervical vertebrae, scapulae, humeri, radii, ulna, metacarpals, femurs, tibias, and fibulas pulled to be tested. Two Spinner dolphins were picked and the cranium, mandible, ribs, cervical vertebrae, coccygeal vertebrae, scapulae, humeri, radii, ulnas, and metacarpals. The researchers used DELTA Premium handheld x-ray fluorescence at 10kV and 40kV power levels (Nganvongpanit et al. 2016a).

The researchers determined that the elements identified in one species were not necessarily found in other species. There were twenty-three elements found in the dog remains, twenty-two elements in the human remains, twenty elements in the elephants, and sixteen elements in the dolphins. From this data, the researchers were able to demonstrate that it is possible to determine different species with the use of x-ray fluorescence. They found that elephants had a 100 percent correct classification rate while humans had 98.7 percent, dogs a 94.9 percent, and dolphins a 92.3 percent. They noted that when trying to distinguish species that one should not use the calcium/phosphorus ratio and that different element ratios should be used. The researchers also wanted to note three limitations that the study had that may have limited the results of the test. These limitations were the small amount of sample number, the constraint that may have had with the x-ray fluorescence, and any potential environmental factors that would have influenced the element levels in the specimens (Nganvongpanit et al. 2016a).

Chapter Four: Methodology for Osteological and X-Ray Fluorescence Analyses

There are two broad scopes of methodology that were used in this thesis. These two methodologies are osteological analysis and x-ray fluorescence. While the use and testing of the x-ray fluorescence is the main subject of this research project, the osteological analysis provides a tremendous amount of information of the skeletal remains that have been tested.

The skeletal remains used in this research include two control skeletons and six disturbed burials and dissociated bones from the Weyerhaeuser site. The two control skeletons are two skeletons that are housed at Ball State University's Anthropology Department and are commonly used as part of classroom curriculum. The two skeletons that were picked for this thesis were BSU-SKL-001 and BSU-SKL-002. The main reason why these skeletons are being used as the control skeletons is that each skeleton is nearly complete with very few small bones missing and that they are each housed in a separate case. The Weyerhaeuser site has both known burials and dissociated bones that have been tested to various degrees based on the results of the osteological analyses. Overall, there are seventeen known burials and forty-two testable dissociated bones from the site; though Burials 1/3, 2, 4, 5, 5a, and 6 are the focus of the research as they are distrubed burials and are the likely candidates for whom the disassociated bones belong. It should be noted that the burials that are the focus of this research are burials that were previously identified and that there may be additional unidentifed burials from this site.

Osteological Analyses

The osteological analysis of the skeletal remains that were tested had metrical and morphological analysis methods performed that follow the guidelines outlined in *Standards for Data Collection from Human Remains* by Jane Buikstra and Douglas Ubelaker (1994). While not every burial or dissociated bones could provide all the desired information, data that was assembled, through measurements and methodologies, was used to estimate age, sex, ancestry, and height, when possible (Buikstra and Ubelaker 1994).

Additional information such as bone color, pathology, and present condition of the bone was collected to help further the efforts of the goals of the research. Other sources (Bass 1995; Spradley and Jantz 2011; Scheuer and Black 2000; Trotter and Gleser 1958; Owsley et al. 1995) were consulted to help provide the answers to the questions of age, sex, height, and ancestry of an individual when it was necessary and beneficial.

The information that was gathered from the osteological analysis of the Weyerhaeuser burials and dissociated bones was completed before they were tested using x-ray fluorescence. This step is an attempt to try to form a preliminary pairing between the known burials and the dissociated bones. Pairings that are determined are based on a mixture of information. Some of the pairings that were estimated were based on information such as estimated age or bone color. To prevent unnecessary work, the Weyerhaeuser remains that were tested with the x-ray fluorescence methodology are the disturbed dissociated bones and *in situ* remains left in disturbed burials.

Osteological Methodologies Used

The methodologies that were used in the osteological analysis of the dissociated bones and known burials are described below. These methodologies were used for age, stature, and sex estimation, along with using bone color for matching.

There were two primary methodologies that were used to estimate age. Krogman and Iscan (1986), McKern and Stewart (1957), Refield (1970), Scheuer and Black (2000), Suchey et al. (1984), and Ubelaker (1989a, 1989b) developed similar methods that examine the epiphyseal closure rate on various bones and bone regions used to estimate the age of an individual. In Buikstra and Ubelaker (1994), a composite figure compiles the information from each of the aforementioned authors into a single place (Buikstra and Ubelaker 1994, 43). The figure in Buikstra and Ubelaker (1994) provides the standard epiphyseal closure age range for several bones. The downside to this figure is that most of the ranges that are provided are for male estimations while there are four ranges that are unisex and two that are for female estimation.

The additional age method used was developed by Lovejoy et al. (1985) and Meindl and Lovejoy (1989) to examine the wear to the morphological changes of the auricular surface on the innominate as an individual age. To do this, the developers of this method break down the wear and changes to this area into eight distinct phases that have relatively different features that appear during each phase that then corresponds to an age group (Buikstra and Ubelaker 1994, 25; Lovejoy et al. 1989; Meindl and Lovejoy 1989).

Two methods (Owsley 1995; Trotter and Gleser 1958) were used to determine the stature of an individual. Both Owsley (1995) and Trotter and Gleser (1958) provide sets of equations that are dependent upon the long bone being tested and the ancestry of the individual.

A number of different sex estimation methods were used during the analysis of the dissociated bones and the known burials based on bones present and their condition. Two morphological traits that were used to estimate sex was the greater sciatic notch and the preauricular surface on the innominate. The greater sciatic notch is scored on a scale of “1” to “5” based on the width of the notch. If a notch is significantly wide, it would be scored a “1” which would be “most likely female” while a narrow notch would be scored “5” indicates “most likely male.” The preauricular sulcus is scored a bit differently than the greater sciatic notch. The scale that used with this trait is a “0 to 4” scale. A “0” indicates that this trait is not present in the specimen while scores “2-4” are indicative that the trait is present, but is represented in various lengths or depths. It is noted that this trait is more commonly seen among females than males (Buikstra and Ubelaker 1994, 18-19).

Another sex estimation method used was Spradley and Jantz (2011). This method utilizes the measurements that are gathered from individual bones during analysis. The method works by taking a measurement, providing the measurement point is on the list of measurements that can be used with this method, and looking at sectioning point and the mean measurement for both males and females. In most, if not all, cases, the male mean measurement will be higher than the sectioning point while the female mean measurement will be lower. Depending on the measurement of the individual's bone, the sectioning point will indicate the sex estimation of that bone. This method also includes the classification rates on how accurate the sex estimation can be for the measurement used (Spradley and Jantz 2011).

The use of bone color became important as research continued due to the possibility that it may help with the pairing of dissociated bones to the burials that they belong. As suggested as a guideline for recording bone color, the Munsell Color Chart was used (Cain 2005; Dupras and Schultz 2014, 316). This is because the Munsell Color Chart examines color by looking at hue, value, and chroma. Bone color changes throughout the decomposition process and can be influenced by various taphonomic and environmental factor (Dupras and Schultz 2014, 316). Hogue and Alvey (2006) also used bone color in the potential of matching dissociated bone to burials and found matches that had the same or similar bone coloring (Hogue and Alvey 2006, 57-58).

X-Ray Fluorescence Methodology

The x-ray fluorescence method used to analyze the bones from the Weyerhaeuser site follows the methodologies that have been presented in the literature with some modifications

(Byrnes and Bush 2016; Gonzalez-Rodriguez and Fowler 2013; Janos et al. 2011; Perrone et al. 2014).

Establishing Experimental and Control Groups

The experimental group includes two groups of remains from the Weyerhaeuser site. The first of these groups include the forty-two testable dissociated bones that were disturbed and recovered from various individuals before the bioarchaeologists were called to the site. The second included the remains of disturbed burials that were chosen for the x-ray fluorescence based on the results of the osteological analysis of the dissociated bones.

As mentioned earlier in this chapter, the control group was selected from the complete skeletons that were available at Ball State University's Anthropology Department. The two skeletons that were chosen for the x-ray fluorescence testing were BSU-SKL-001 and BSU-SKL-002. They were selected based on the condition and near completeness of the skeletons.

X-Ray Fluorescence Testing Procedures

To help with the placement of the bones with the results, points on the bones were selected for each bone. In Perrone et al., the researchers chose one point for analysis on each bone to account for variability in the bones (Perrone et al. 2014). To take precautions due to the condition of the bones, three points were tested each bone, if possible, instead of just one point as done in the Perrone et al. (2014) experiment.

The points chosen for long bones occur at the proximal, midshaft, and distal portions on the ventral side of the long bones present. Flat bones, due to their fragile nature, will have points taken from the proximal end, the middle region of the bone, and the distal end of the bone or the area opposite of the proximal end. The particular points tested on the bones will be shown in photographs of one of the control skeletons found in Appendix 1. Due to the fragmented nature of the dissociated bones, photographs of the dissociated bones are also provided in the appendix to show the location of the points.

To perform the analyses, Olympus™ Innov-X Delta Premium portable handheld x-ray fluorescence analyzer was used. Five standards were used to test the accuracy of the x-ray fluorescence. These standards are a blank standard (SiO2), Montana I Soil standard (NIST 2710a), Montana II Soil standard (NIST 2711a), a bone ash standard (NIST 1400), and a bone meal standard (NIST 1486).

Due to the size of some of the bones, a lead chamber was not able to be used for this research. Instead, a camera stand was used to hold the x-ray fluorescence machine in place during testing. Both small and large bones were tested with the camera stand setup to provide consistency in testing methods. With the camera stand setup, there was no limitation on the size of the bone tested, but the risk of accidentally picking up radiation from when the tests are running is slightly higher. As a standard when using x-ray fluorescence machinery, a dosimeter ring was worn to detect the amount of radiation exposure. The ring is tested at the end of each quarter and relays the amount of radiation exposure back to the researcher.

As stated earlier, each bone was tested with the x-ray fluorescence at three different points, when possible. Due to the size of some bone fragments, only one or two points were tested. Each point was tested for ninety seconds. During this ninety seconds, there was a sequence of three beams at different power levels that each last for thirty seconds. The first two beams have a power level of 40kV while the third beam has a level of 15kV. The different power levels help detect different elements.

In the literature, the elements that had been looked at were sodium, magnesium, silicon, phosphorus, potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, and zinc (Fulton et al. 1986; Gonzalez-Rodriguez and Fowler 2013; Perrone et al. 2014). Unfortunately, the model used for this research does not read elements that fall under the element number 15 or accurately measure phosphorus. Due to this information, testing for sodium, magnesium, and silicon was not available. This left the possibility to test eleven elements in this project: potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, and zinc.

It was common practice to prepare the bone in some form, either washing with deionized water or altering the bone in some way (Gonzalez-Rodrigeuz and Fowler 2013; Janos et al. 2011; Perrone et al. 2014). Due to the poor and fragmented condition of the Weyerhaeuser remains a decision was made not to wash the bones a second time. While a few of the bones are in good condition, the majority of bones from the site may have a deterioration in condition if washed that may ultimately leave them untestable.

Analyzing X-Ray Fluorescence Data

The data gathered from the x-ray fluorescence testing were exported from the machine into Microsoft Office Excel to perform analysis of the data. The exported data was then cleaned to correct labeling errors and eliminate error runs that occurred during testing. It was at this time that some elements were eliminated because they were not detected during testing along with elements that were not detected in the majority of the bones. The elements eliminated were sulfur, chlorine, arsenic, selenium, rubidium, strontium, yttrium, zirconium, molybdenum, silver, cadmium, tin, antimony, tungsten, mercury, lead, bismuth, thorium, and uranium. Phosphorus was also eliminated due to the possibility that the machine would not accurately record the element amount in the bone. This left potassium, calcium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, and zinc as possible elements that could be used for the bone comparison.

The next step was to create averages for each bone that was tested. This means that on average, a single bone would have three runs compressed into a single average to facilitate a smooth comparison between the dissociated bones and the burials. This step would also be done on the bones that only had one or two runs performed.

It was also during this step that the number of elements that are used for analysis was reduced to potassium, calcium, titanium, vanadium, chromium, manganese, iron, copper, and zinc. These elements were chosen because the machine detected results consistently while other elements were either not detected during testing or not detected in a number of the bones tested. These nine elements were used to perform discriminant function analyses to identify where bone elements may be placed. In Perrone et al. (2014), it was suggested that the combination of elements that were used in the analysis of the x-ray fluorescence data varies from case to case.

Discriminant function analysis was used to analyze this data because it is capable of assessing if an unknown item belongs within a group (Moore 2013, 91-116); with this research, if a dissociated bone belongs to a burial. For both the control and experimental groups, the skeletons/burials/dissociated bones were given a number corresponding to their grouping. Control skeletons 1 and 2 were assigned numbers “1” and “2,” respectively, for that portion of the experiment. In the experimental group, the dissociated bones were given a collective number of “0” while the burials from the site were given numbers corresponding with their burial number, except for Burial 5a that was assigned the number of “55.” The control group tested both skeletons against each other at the same time, whereas in the experimental group the dissociated bones were tested against each burial individually. To perform the discriminant function analyses, the steps from Daria Newfeld’s Youtube video “365, ch 10, discriminant analysis in Excel” were used and modified to fit the needs of this analysis (Newfeld 2014).

At this point, the data was run through a regression formula in the “Data Analysis” section in the “Data” tab. The y-input range selected was the assigned numbers given to every bone/burial/skeleton while the x-input range was the data from the nine elements listed above. From this data, a table will appear with a list of coefficients that are needed for the next step to create a set of preliminary predictions of where each bone belongs. Each bone in the test will have a formula ran to create a tentative placement; the formula is as followed (Newfeld 2014):

= intercept coeffiecent+(potassium coefficient*potassium data)+(calcium coefficient*calcium data)+(titanium coefficient*titanium data)+(vanadium coefficient*vanadium data)+(chromium coefficient*chromium data)+(manganese coefficient*manganese data)+(iron coefficient*iron data)+(copper coefficient*copper data)+(zinc coefficient*zinc data)

Following this, the preliminary predictions will be tested with a cut-off point. This further helps to place the bones with their proper burials as the preliminary predictions will likely not give a number without decimals following. The first part of this step is to create a cut-off point number. Creating this number involves multiple formulas that look at the number of bones tested in each group (example: n0=count(range of one group)) and the average of the preliminary predictions (example: d0-bar=average(range of one group’s preliminary predictions)). Once this data is collected for both groups in the test, the following formula is run to create the cut-off point (Newfeld 2014):

Cut-off Point=((n0*d0-bar)+(n1*d1-bar))/(n0+n1)

With this number, the following formula is tested against all the bones in the test in order to provide a final predication of which group the bones belong in (Newfeld 2014):

=if(preliminary predications<cut-off point, 0,1)

One additional step was taken with the control group to look at the misclassification of this method with known skeletons. An “if” function looks to see if the original placement of the bone is equal to the final prediction. The number of “yes” answers is then used to create the percent of correct placement between the two skeletons (Newfeld 2014).

Chapter Five: Osteological Recording and Measurements of the Disassociated Bones from the Weyerhaeuser Site

This chapter reviews the results of the osteological analyses of the dissociated bones that were collected by construction workers, the coroner, and from the back dirt piles. These specimens had been disturbed by machinery and humans before Hogue and Alvey arrived at the site. Something to note is that all single bone elements that were matched to a burial in the Hogue and Alvey report (2006) are being treated as dissociated bones in this research to test the x-ray fluorescence.

As mentioned in an earlier chapter, the methods used throughout this chapter are found in Buikstra and Ubelaker (1994) and supplemented with the Munsell Color Chart and other osteological methods as needed. For the individual bone fragments, the form “Inventory Recording Form for Commingled Remains and Isolated Bones” from *Standards for Data Collection from Human Skeletal Remains* by Jane E. Buisktra and Douglas H. Ubelaker was utilized to inventory the disassociated remains. For this form, each bone is individually recorded by bone element and side, if possible, as well as the portion of the bone present for auricular regions, vertebrae, and long bone diaphyses (Buikstra and Ubelaker 1994).

There is coding for both the siding of the bone and the portion of the bone present. The coding for siding is as followed: “L” is for the left side, “R” is for the right side, “B” is for both sides, “M” is for midline, and “?” is where the side could not be determined. The coding to indicate which portion of the bone is present in the previously mentioned areas is as followed:

“PE” for proximal epiphysis, “P1/3” for proximal third of the diaphysis, “M1/3” for middle third of the diaphysis, “D1/3” for distal third of the diaphysis, “DE” for distal epiphysis, “B” for body of the vertebrae or centrum, and “NA” for neural arch. Next, is to record the level of completeness of the bone fragment. This is a three number system where “1” stands for greater than 75percent present, “2” for between 25-75 percent, and “3” for less than 25 percent of the bone is present (Buikstra and Ubelaker 1994).

Dissociated Bones

The dissociated remains from this site include bone elements from the human skeletons. These bones are all estimated to be likely or definitively adult remains of unknown sex. To list all the dissociated bone elements found in this site, they are separated into five categories representing regions of the skeleton: cranial, axial, upper body, lower body, and miscellaneous fragments.

Cranial Region

The bones in this section include bones that belong to the cranium and the mandible, including teeth. In total, there were three parietals, one temporal, a maxilla with three teeth, a mandible with three teeth, two mandibular molars, one maxillary canine, and one mandibular incisor. These are visible in **Table 1** below.

Table 1. Dissociated Bone Inventory for Head Region

Bone	Side	Segment	Completeness	Count	Bone Color
Parietal (#1)	Rt?	-	2	1	7.5YR 5/4
Parietal (#2)	?	-	2	1	7.5YR 5/3
Parietal (#3)	?	-	3	1	7.5YR 4/4
Temporal (#1)	Rt	-	2	1	7.5YR 4/4
Maxilla w/ I^2, C^1, P^1, P^2	Lt	-	Maxilla – 2 Teeth – 1	5	7.5YR 3/2
Mandible w/ C_1, P_1, P_2	Lt	-	2	4	7.5YR 3/4 and 5/6
Maxillary C^1	Rt	-	1	1	-
Mandibular I2	Rt	-	1	1	-
Mandibular M_1	Rt	-	2	1	-
Mandibular M1	Rt	-	2	1	-

For measurements, only two bones were able to obtain any measurements. The right Temporal #1 has a mastoid length at 31.93 millimeters. The other bone that provided some measurements is the left mandible. The chin length is 32.07 millimeters, the height of the mandibular body is 32.27 millimeters, and the breadth of the mandibular body is 12.25 millimeters.

While the bone color is recorded, it was not recorded for the teeth because they represent the time of life during their development and not of the last couple years so it would not provide viable information for this research. If the remains had indicated that some of the dissociated bones were juvenile or infant, then the color would have been recorded.

Axial Region

The bones in the axial region include vertebrae and ribs (**Table 2**). In total for this region, there was one cervical vertebra, three thoracic vertebrae, two lumbar vertebrae, eighteen neural arch fragments, thirty-five rib fragments.

Table 2. Dissociated Bones of the Axial Region

Bone	Side	Segment	Completeness	Count	Bone Color
Cervical Vertebra	-	B	2	1	7.5YR 7/4
Thoracic Vertebrae	-	B	1	3	7.5YR 6/4
Lumbar Vertebrae	-	B	1	2	7.5YR 5/4
Vertebrae Fragments	-	NA	3	11	7.5YR 5/4
Rib Fragments	?	-	3	34	-
Rib Fragment	?	-	3	1	7.5YR 4/2
Neural Arches	1.	NA	3	7	-

The rib and neural arch fragments, except for one rib fragment, did not have their bone color recorded because they will not be tested with the x-ray fluorescence. This decision was made based on the fact that the fragments are rather small and numerous. No measurements were taken on the specimens from this section due to either how incomplete the bone was or the degradation of the bone areas where measurements would be taken.

Upper Body Region

The bones in this section include the clavicle, scapula, humerus, ulna, radius, carpals, and metacarpals (phalanges are in a later section). In total, there was one clavicle, six scapulae, two radii, two unsided metacarpals, one 3rd metacarpal, seven humeri, and two ulnas (**Table 3**). **Table 4** provides all the measurement that were gathered on the bones from the Upper Body Region.

Table 3. Dissociated Bones for the Upper Body Region

Bone	Side	Segment	Completeness	Count	Bone Color
Clavicle (#1)	Rt	-	1	1	5YR 5/4
Scapula (#2a)	Rt	-	3	1	7.5YR 4/3
Scapula (#2b)	Rt	-	2	1	7.5YR 5/4
Scapula (#3)	Rt	-	3	1	7.5YR 3/3
Scapula (#1a)	Lt	-	3	1	7.5YR 3/2
Scapula (#1b)	Lt	-	3	1	7.5YR 4/2
Scapula (#3)	?	-	3	1	7.5YR 4/1
Humerus (#1a)	Rt	P1/3, M1/3, D1/3, DE	1	1	7.5YR 4/4

Humerus (#1b)	Rt	P1/3, M1/3, D1/3, DE	1	1	7.5YR 3/1
Humerus (#2)	Rt	P1/3, M1/3, D1/3, DE	1	1	7.5YR 4/4
Humerus (#3)	Rt	P1/3, M1/3, D1/3, DE	1	1	7.5YR 5/3
Humerus (#1)	Lt	P1/3, M1/3, D1/3	1	1	7.5YR 5/4
Humerus (#2)	Lt	P1/3, M1/3, D1/3	1	1	7.5YR 4/3
Humerus (#3)	?	PE	3	1	7.5YR 5/3
Radius (#2)	Rt	P1/3, M1/3, D1/3	1	1	5YR5/4
Radius (#1)	Lt	P1/3, M1/3, D1/3	1	1	5YR 5/4
Ulna (#1)	Rt	P1/3, M1/3, D1/3	1	1	7.5YR 4/2
Ulna (#1)	Lt	P1/3, M1/3, D1/3	2	1	7.5YR 4/2
3rd Metacarpal	Lt	-	1	1	7.5YR 5/3
Metacarpals	?	-	1 to 2	2	7.5YR 5/3

Table 4. Bone Measurements from the Dissociated Bones from the Upper Body Region

Bone	Side	Measurement Name	Measurement (millimeters)
Clavicle #1	Rt	Anterior-Posterior Diameter at Midshaft	15.02mm*
		Superior-Inferior Diameter at Midshaft	14.07mm*
Humerus #1a	Rt	Maximum Diameter at Midshaft	23.97mm*
		Minimum Diameter at Midshaft	22.99mm*
Humerus #1b	Rt	Epicondylar Breadth	62.86mm
		Maximum Diameter at Midshaft	24.96mm
		Minimum Diameter at Midshaft	20.71mm
Humerus #2	Rt	Maximum Diameter at Midshaft	22.71mm*
		Minimum Diameter at Midshaft	17.84mm*
Humerus #3	Rt	Maximum Diameter at Midshaft	22.08mm*
		Minimum Diameter at Midshaft	18.8mm*
Humerus #1	Lt	Maximum Diameter at Midshaft	21.22mm*
		Minimum Diameter at Midshaft	19.46mm*
Humerus #3	Lt	Maximum Diameter at Midshaft	23.93mm*
		Minimum Diameter at Midshaft	20.29mm*
Radius #2	Rt	Anterior-Posterior at Midshaft	14.01mm*
		Medial-Lateral at Midshaft	13.77mm*
Ulna #2	Rt	Anterior-Posterior Diameter	17.23mm
		Medial-Lateral Diameter	14.8mm
Ulna #1	Lt	Anterior-Posterior Diameter	17.71mm*
		Medial-Lateral Diameter	13.0mm*
Ulna #2	Lt	Anterior-Posterior Diameter	15.35 mm

Medial-Lateral Diameter	15.19mm

*Points for measurements were estimated.

Lower Body Region

The bones in this section include the innominate, sacrum, coccyx, femur, tibia, fibula, and the bones of the feet. In total, there was one ilium, one ischium, two femurs, one tibia, and one talus (**Table 5**).

Table 5. Dissociated Bones of the Lower Body Region

Bone	Side	Segment	Completeness	Count	Bone Color
Ischium (#1)	Rt	-	1	1	7.5YR 6/3
Ilium	?	-	3	2	7.5YR 5/3
Femur (#2)	Lt	PE	3	1	7.5YR 8/2
Tibia (#1)	Lt	P1/3, M1/3, D1/3	2	1	7.5YR 5/4
Talus (#1)	Rt	-	2	1	7.5YR 6/4

There were two bones in this region that were capable of providing measurements. Left femur #2 was able to provide the measurement for the maximum diameter of the femur head at 48.52 millimeters. The left tibia #1 provided three measurements. The measurements are the maximum diameter of the nutrient foramen at 24.23 millimeters, the medial-lateral diameter at nutrient foramen at 33.18 millimeters, and the circumference at the nutrient foramen at 92 millimeters.

Miscellaneous Bones

The bones in this section are unidentifiable. There are one-hundred and twenty-six unidentified miscellaneous bones recovered. Also, in this section are two phalanges (**Table 6**). While phalanges belong to either the hand or the foot, due to the similar size of phalanges in those two locations the phalanges recovered could not be placed in either category.

Table 6. Miscellaneous Dissociated Bones

Bone	Side	Segment	Completeness	Count	Bone Color
Phalanges	-	-	1	2	7.5YR 7/4
Misc. Fragments	-	-	3	126	-

Bone Matching Amongst Dissociated Bones

This conclusion examines the possible bone pairings that may exist amongst the dissociated bones based on bone color and measurements. The estimated pairing of the dissociated and associated bones will occur in a later chapter and look at the bone color and sex estimation, determined in said chapter, to make the pairings.

Bone Color Pairing

The bone grouping that is being looked at is centered on bone color. Due to this broad category, there will be the same bone elements placed in the same category. This likely means that there are burials that have similar bone color to each other.

Based on bone color, there are six different groups that are defined. The first group defined is based on the bone colors 7.5YR 3/1 through 7.5YR 3/4. The bones in this group are the maxilla with four teeth, the mandible with three teeth, right scapula #3, left scapula #1a, and right humerus #1b.

The colors of 7.5YR 4/1 through 7.5YR 4/4 form the second group. Bones in this group include parietal #3, temporal #3, rib fragments, right scapula #2a, left scapula #1b, unsided scapula #3, right humerus #1a, right humerus #2, left humerus #2, right ulna #1, and left ulna #1.

The third group formed from the bone colors of 7.5YR 5/3 and 7.5YR 5/4. The bones that fell into this group were parietal #1, parietal #2, lumbar vertebrae, vertebrae fragments, right clavicle #1, right scapula #2b, right humerus #3, left humerus #1, unsided humerus #3, right radius #2, left radius #1, 3rd left metacarpal, unsided metacarpal, unsided ilium, and left tibia #1.

The last three groups are minuscule groups with less than three bones in each group. The fourth group is defined by the bone colors of 7.5YR 6/3 and 7.5YR 6/4 and contained the bones of the thoracic vertebrae, right ischium #1, and right talus #1. The fifth group is based on the color of 7.5YR 7/4 and contains the cervical vertebra and the phalanges. The last group is created around 7.5YR 8/2 and only includes the left femur #2.

Measurement Pairing

The possible pairing group looked at the possible paired bones amongst the dissociated bones to see if there are similar bone measurements to create possible pairings. In the end, there are three tentative matches. The first of these matches are right ulna #2 and left ulna #1. The anterior-posterior and medial-lateral diameter of the right ulna was 17.23mm and 14.8mm while the left ulna 17.71mm and 13.0mm,

The remaining two matches occurred between the humeri present. The first pair occurred between the right humerus #1b and left humerus #3. The right humerus has a maximum/minimum diameter at the midshaft of 24.96mm and 20.71mm while the left humerus has a maximum/minimum diameter at the midshaft of 23.93mm and 20.29mm. The last pair that was defined is amongst right humerus #3 and left humerus #1. The maximum/minimum diameter at midshaft of the right humerus #3 is 22.08mm and 18.8mm while the left humerus #1 is 21.22mm and 19.46mm. While these pairs amongst the humeri were formed based on the closest similar measurements, there are other humeri that have very similar measurements as well.

Conclusions

Examining the results from the matching performed in this chapter, it is best to look at the results from the bone color as it provides a more comprehensive insight of the bones possibly final placement (Cain 2005; Dupras and Schultz 2014, 316). Through the bone color groupings, there are likely six burials with distinct bone coloring from each other. Though, due to there being the same bone element within some of these groups, it is more likely that the burials may have varying bone color shades in a single burial or there are additional individuals present that cannot be accounted for by what remains of the disturbed burials. No tentative pairings will be made until after the examination of the burials and further analysis of the dissociated bones.

Chapter Six: Osteological Analysis of Associated Bones from the Disturbed Weyerhaeuser Burials

Weyerhaeuser Burials

In this chapter are the results of the osteological analyses of the Burials 1/3, 2, 4, 5, 5a, and 6 excavated at the site. The examination of these burials occurred because they were the disturbed burials from the Weyerhaeuser site, along with all having an adult age estimation. As mentioned in the earlier chapter, the methods used for this research are found in Buikstra and Ubelaker (1994) and supplemented with outside sources when needed, such as for ancestry and stature estimation.

Burial 1/3

The bones present in this burial are a right occipital, right tibia, left tibia, right fibula, a left fibula, right and left calcaneus, right and left talus, two tarsals, eight metatarsals, and twelve phalanges (**Table 7**). There are additional bone fragments associated with Burial 1/3, yet the fragments are too fragmented for identification or analysis.

Table 7. Bone Inventory for Burial 1/3

Bone Present	Side	Fragmentation Level	Bone Color[1]
Occipital	Right	3	7.5YR 4/3
Tibia	Right	1	7.5YR 4/1
Tibia	Left	1	7.5YR 6/3

Fibula	Right	1=Diaphysis, 3= Epiphyses	5YR 6/4
Fibula	Left	1 (Just Diaphysis)	7.5YR 6/3
Talus	Right	2	N/A[2]
Talus	Left	1	N/A[2]
Calcaneus	Right	2	N/A[2]
Calcaneus	Left	1	N/A[2]
Tarsal	Unsided	1	N/A[2]
Metatarsals	Left – 1 Right – 1 Unsided – 6	1	N/A[2]
Foot Phalanges	Left – 5 Unsided – 7	1	N/A[2]

[1] Bone Color was determined using the Munsell Soil Color Charts.

[2] N/A Bone color was not recorded due to the size of the bones.

There is some form of discoloration is present on a number of bones in this burial. This discoloration for the majority of these bones is likely caused by soil diagenesis (Dupras and Schultz 2014) The color of the discoloration is recorded using the Munsell Soil Color Charts. The right occipital has some discoloration present along the suture line. The discoloration of the right occipital is 7.5YR 4/3. On the right tibia, the discoloration is present in the middle and distal third of the bone and recorded as 5YR 2.5/1. The left tibia has discoloration on the distal third that is the color of 10YR 2/1. The right fibula has discoloration present on the middle and distal third of the bone with discoloration of 7.5YR 3/1. The left fibula had discoloration present on the entire surface except for the proximal and distal third of the diaphysis. The discoloration of the left fibula is 7.5YR 3/1. The discoloration present on the right and left tibia and fibula suggest that something was, at one point, laid across the bones.

Table 8. for Bone Measurements for Burial 1/3

Left Tibia		**Left Fibula**	
Length	448mm		
Maximum Proximal Epiphyseal Breath	65.35mm	Maximum Diameter of Midshaft	13.78mm
Maximum Distal Epiphyseal Breath	46.61mm		
Max. Diameter at the Nutrient Foramen	39.29mm	**Left Calcaneus**	
Med. Lat. Diameter at Nutrient Foramen	29.87mm	Maximum Length	87.93mm
Circumference at the Nutrient Foramen	110mm	Middle Breadth	45.90mm

For the measurements, as is standard practice, both the left tibia and fibula were used to record measurements, with all measurements in millimeters (**Table 8**). Due to the fragmentation of the bones, some of the bones present are unable to be measured or have all the measurements listed on a record sheet.

The closure of the epiphyses is used to estimate the age of the individual. Due to the epiphyseal closure on the long bones present being complete with obliterated closures, the individual present in Burial 1/3 is estimated to be an adult. The estimated epiphyseal closure of the tibia is between the age of thirteen and sixteen years old in males and then between fifteen to nineteen years old in females. For the fibula, the epiphyseal closure rate is between twelve and fourteen years old in males and fifteen to seventeen years in females (Buikstra and Ubelaker 1994, 43; Krogman and Iscan 1986; McKern and Stewart 1957; Redfield 1970; Scheuer and Black 2000; Suchey et al. 1984; Ubelaker 1989a, 1989b).

Using the regression equations created by Owsley (1995), the stature of the individual is estimated using the tibia. The formula used for African-American Male is as followed:

Stature = 0.10521 (Tibia Length) + 26.26 (+/- 3.8”)

0.10521 (448mm) + 26.26 = 73.39” (+/- 3.8”)

The length of the tibia is in millimeters for the equation, but later converts to feet and inches during the duration of the equation. For the individual in Burial 1/3, the individual is estimated to be 73.39” +/- 3.8” or 6’1” +/- 3.8”. Sex estimation is conducted using Spradley and Jantz (2011). Based on the findings, the individual is a male (**Table 9**).

Table 9. Spradley and Jantz 2011 Sex Estimation for Burial 1/3

Bone Name	Measure-ment Name	Measure-ment	Female Mean	Female Standard Deviation	Male Mean	Male Standard Deviation	Section-ing Point	Classsifi-cation Rate	Indicated Sex
Tibia	Maximum Diameter at the Nutrient Foramen	39.29mm	32.23mm	2.81mm	37.31 mm	2.85mm	35mm	80%	Male
Tibia	Circumfer-ence at Nutrient Foramen	110mm	88.05mm	5.92mm	101.38m m	8.1mm	95mm	79%	Male
Tibia	Length	488mm	375 mm	23.91mm	410.18 mm	23.39mm	393mm	79%	Male
Calcan-eus	Maximum Length	87.93mm	76.45mm	4.62mm	85.38 mm	4.74mm	81mm	83%	Male
Calcan-eus	Middle Breadth	45.90mm	38.89mm	2.4mm	44.06 mm	2.84mm	41mm	79%	Male

Overall, based on the findings, it is estimated that the individual found in Burial 1/3 is an adult male and has a stature of 6’1” +/- 3.8”. Due to the remains that were present in this burial, ancestry estimation was unable to be calculated.

Burial 2

The remains recovered from Burial 2 include the right and left patella, left ilium, right and left ischium, left acetabulum, right and left auricular surface, right and left radius, right and left ulna, right and left femur, right and left tibia, right and left tibia, right and left fibula, right and left calcaneus, right and left talus, eleven carpals, five metacarpals, twenty-six hand phalanges, nine tarsals, ten metatarsals, and nineteen foot phalanges (**Table 10**). There are also two lumbar and three thoracic vertebrae identified, but due to the fragmentation of these vertebrae, the specific numbering of the vertebrae is not possible. Additional fragments belonging to the sacrum, the vertebrae, and ribs were recovered with this burial, yet the fragments did not allow for further identification.

Table 10. Bone Inventory for Burial 2

Bone Present	Side	Fragmentation Level	Bone Color[1]
Patella	Right	1	7.5YR 4/3
Patella	Left	1	7.5YR 5/4
Ilium	Right	2	7.5YR 4/3
Ilium	Left	1	7.5YR 3/2
Ischium	Right	2	7.5YR 4/3
Ischium	Left	3	7.5YR 3/2
Acetabulum	Left	2	7.5YR 3/2
Auricular Surface	Right	2	7.5YR 4/3
Auricular Surface	Left	2	7.5YR 3/2
Radius	Right	1	7.5YR 4/4
Radius	Left	1 (Just Diaphysis)	7.5YR 4/4
Ulna	Right	1	7.5YR 5/4
Ulna	Left	1 (Distal Epiphysis Missing)	7.5YR 5/6
Femur	Right	1	7.5YR 4/3

Femur	Left	1	7.5YR 4/3
Tibia	Right	1	7.5YR 4/3
Tibia	Left	1 – Diaphysis and Distal Epiphysis 2 – Proximal Epiphysis	7.5YR 4/3
Fibula	Right	1 (Missing Proximal Epiphysis)	7.5YR 4/3
Fibula	Left	1 (Missing Proximal Epiphysis)	7.5YR 5/3
Talus	Right	1	
Talus	Left	1	
Calcaneus	Right	1	
Calcaneus	Left	2	
Carpals	Left – 6 Right – 6	Left – 1 Right – 1	
Metacarpals	Left – 1 Right – 3 Unsided – 1	Left – 1 Right – 1 Unsided - 1	
Hand Phalanges	Unsided – 26	Unsided – 1	
Tarsals	Left – 2 Right – 2 Unsided – 5	Left – 1 Right – 1 Unsided – 2	
Metatarsals	Left – 5 Right – 5	Left – 1 Right – 1	
Foot Phalanges	Left – 2 Right – 2 Unsided - 15	Left – 1 Right – 1 Unsided - 1	

[1] Bone Color was determined using the Munsell Soil Color Charts

Due to various fragmentation levels of the bones in Burial 2, measurements were taken from the left femur, left tibia, and right calcaneus in millimeters (**Table 11**).

Table 11. Table for Bone Measurements for Burial 2

Bone	Name of Measurement	Measurement in Millimeters (mm)
Femur	Maximum Length	481mm
	Bicondylar Length	480mm
	Ant.-Post. Subtrochanteric Diameter	27.64mm
	Medial-Lateral Subtrochanteric Diameter	34.24mm
	Anterior-Posterior Midshaft Diameter	31.02mm
	Medial-Lateral Midshaft Diameter	26.27mm
	Midshaft Circumference	86mm
Tibia	Maximum Distal Epiphyseal Breadth	49.38mm
	Max. Diameter at the Nutrient Foramen	39.02mm
	Med.-Lat. Diameter at the Nutrient Foramen	33.62mm
	Circumference at the Nutrient Foramen	100mm
Calcaneus	Maximum Length	81.04mm
	Middle Breadth	43.70mm

The sex estimation of the individual found in Burial 2 is based on the innominate morphological traits of the greater sciatic notch and the preauricular sulcus and the measurements from the left femur, left tibia, and right calcaneus. The greater sciatic notch on both the right and left ilium scored as a “4” which suggest, from this method that the individual, in this burial is probably male. The preauricular sulcus is scored a bit differently than the greater sciatic notch. The score recorded for this trait on both the right and left side was a “0,” which estimates the individual as male. With the scores from the greater sciatic notch and the preauricular sulcus, the sex estimation of the individual based on morphological traits found in Burial 2 is male (Buikstra and Ubelaker 1994).

Based on the measurements from the left femur, left tibia, and right calcaneus, a sex estimation can also be estimated using Spradley and Jantz (2011). Based on the conclusions from the morphological and measurement estimations, the individual from this burial is male (**Table 12**).

Table 12. Spradley and Jantz 2011 Sex Estimation for Burial 2

Bone Name	Measure-ment Name	Measure-ment	Female Mean	Female Standard Deviation	Male Mean	Male Standard Deviation	Section-ing Point	Classsifi-cation Rate	Indicated Sex
Femur	Anterior-Posterior Sub-Trochanter Diameter	27.64mm	25.86mm	2.56mm	28.73mm	2.28mm	27mm	83%	Male

Femur	Bicondylar Length	480mm	444.94mm	2.94mm	484.32mm	25.9mm	465mm	81%	Male
Femur	Midshaft Circumference	86mm	82.7 mm	5.23mm	91.78 mm	10.43mm	87mm	79%	Female
Femur	Max Length	481mm	448.45mm	27.6mm	488.9 mm	25.98mm	469mm	79%	Male
Tibia	Maximum Diameter at the Nutrient Foramen	39.02mm	32.23mm	2.81mm	37.31 mm	2.85mm	35mm	80%	Male
Tibia	Circumference at Nutrient Foramen	100mm	88.05mm	5.92mm	101.38mm	8.1mm	95mm	79%	Male
Calcaneus	Maximum Length	81.04mm	76.45mm	4.62mm	85.38 mm	4.74mm	81mm	83%	Male
Calcaneus	Middle Breadth	43.70mm	38.89mm	2.4mm	44.06 mm	2.84mm	41mm	79%	Male

Due to limited bones with this burial, age estimation was conducted by using the auricular surface. For Burial 2, the right auricular surface scored as a “Phase 4.” Phase 4 represents an age range of 35 to 39 years old. The left auricular scored as a “Phase 3” which represents the age range of 30 to 34 years old. Based on the two scores for the auricular surface, an age range for the individual in Burial 2 is estimated to be between the ages of 33 to 39 years old (Buikstra and Ubelaker 1994, 25; Lovejoy et al. 1989; Meindl and Lovejoy 1989).

Stature estimate of the individual found in Burial 2 uses two separate stature methods (Owsley 1995; Trotter and Gleser 1958). The first of these methods is the regression equations created by Owsley (1995). The regression equation used is for a femur belonging to an African-American male and is as followed:

Stature = 0.08388 (Femur Length (mm)) + 28.57 (+/- 4.0”)

0.08388 (481mm) + 28.57 = 68.91” (+/- 4.0”)

The individual in Burial 2 is estimated to be 68.91” +/- 4.0” or 5’8.91” +/- 4.0” using the regression equations (Owsley 1995). The stature equations developed by Trotter and Gleser (1958) is also used and followed the same variables used in the previous equation:

Stature = 2.11 (Femur Length (cm)) + 70.35 (+/- 3.94cm)

2.11 (48.1cm) + 70.35 = 171.841cm (+/- 3.94cm)

The result of the equation is that the stature estimation is 171.841 cm +/- 3.94cm or 5’7.65” +/- 1.55” (Trotter and Gleser 1958). From the results of stature methods, both methods produce results that were roughly within an inch of each other. The results of the Trotter and Gleser method are used to provide a refined stature estimation for the final stature estimation.

In summary, most of the skeleton for the individual found in Burial 2 is present, minus cranial bones, vertebrae, ribs, and both humeri. Based on estimations, this individual is probably male based on the greater sciatic notch, the preauricular sulcus, and the measurements. The age of the individual is between 33 to 38 years old based on the appearance of the auricular surface with a stature estimation of 5’7.65” +/-1.55”. Ancestry was not estimated as no cranial bones were present.

Burial 4

The remains found in Burial 4 include the left frontal, left and right occipital, left and right temporal, left and right mandible, left and right clavicle, the left body of the scapula, the second cervical vertebrae, additional cervical vertebrae, left humerus, left ulna, and twenty-nine teeth (**Table 13**).

Table 13. Bone Inventory for Burial 4

Bone	Side	Fragmentation	Bone Color[1]
Frontal	Left	2	7.5YR 4/3
Occipital	Left	2	7.5YR 5/4
Occipital	Right	2	7.5YR 5/4
Temporal	Left	2	7.5YR 6/6
Temporal	Right	2	7.5YR 4/3
Mandible	Left	2	7.5YR 5/4
Mandible	Right	3	7.5YR 5/4
Clavicle	Left	2	7.5 YR 6/4
Clavicle	Right	2	7.5YR 4/3
Scapula Body	Left	3	7.5YR 5/4
Axis (C2)[2]		1	
Cervical Vertebrae Centrum (Between C3-		2	

C6)[2]			
Humerus	Left	1 (Just Diaphysis)	7.5YR 5/4
Ulna	Left	1 (Missing Distal Epiphysis)	7.5YR 5/4

[1] Munsell Color Chart
[2] The color of the vertebrae was not recorded.

An age estimation on this individual indicates the individual is an adult based on the epiphyseal closure present on the proximal epiphysis of the left ulna (Buikstra and Ubelaker 1994, 43; Krogman and Iscan 1986; McKern and Stewart 1957; Redfield 1970; Scheuer and Black 2000; Suchey et al. 1984; and Ubelaker 1989a, 1989b).

Along with the age estimation of the non-teeth bones present in the burial, the teeth also indicate that this individual is an adult over the age of thirty-five based on the sequencing of tooth eruption developed by Ubelaker (1989a). This suggests that all teeth have fully formed and erupted (**Table 14**, Table 15) (Ubelaker 1989a).

Table 14. Tooth Inventory for Burial 4

Tooth Number	Tooth Presence	Development	Wear (Total)	Caries	Calculus
1	1	14	16	2, 1	1
2	1	14	16	2	2
3	1	14	16	2	2
4	1	14	3	0	1
5	1	14	2	0	1
6	1	14	2	0	1
7	1	14	3	0	0

8	1	14	3	0	0
9	1	14	3	0	0
10	1	14	3	0	0
11	1	14	4	0	0
12	1	14	3	1	0
13	1	14	3		0
14	1	14	16	2, 2	1
15	1	14	16		1
18	1	14	16	3	0
19	1	14	16	0	0
20	2	14	3	2	0
21	2	14	3	0	0
22*	2	14	5	0	0
23	2	14	3	0	1
24	2	14	3	0	0
25	2	14	3	0	0
26	2	14	3	0	0
27	1	14	3	0	1
28	7 (1)	14	0	6	0
29	1	14	3	0	1
30	7 (2)	14	0	6	0
32	1	14	16	2	0

*Tooth 22 is deciduous

Table 15. Dental Measurements for Burial 4*

Maxillary								
Tooth	**I^1**	**I^2**	**C^1**	**PM^1**	**PM^2**	**M^1**	**M^2**	**M^{3**}**
Mesiodistal Diameter	8.08	6.74	7.50	7.62	7.41	12.42	12.22	11.97
Buccolingual Diameter	7.22	7.90	8.51	10.33	10.38	10.12	10.06	10.80
Crown Height	10.38	10.94	10.15	7.30	7.12	7.14	7.58	6.54
Mandibular								
Tooth	**M_3^{**}**	**M_2**	**M_1**	**PM_2**	**PM_1**	**C_1**	**I_2**	**I_1**
Mesiodistal Diameter	12.30	13.12	13.41	8.21	7.44	--	6.25	5.17
Buccolingual Diameter	11.46	9.77	11.49	9.77	8.94	5.48	6.488	6.00
Crown Height	5.85	7.40	7.15	6.86	7.14	3.82	7.87	7.54

*All measurements are in millimeters
**Right side was used in measurements when the left side was not available for measurements

There are a few dental abnormities with the remains in Burial 4. While all other teeth present are permanent teeth, Tooth 22 is a deciduous tooth. The permanent tooth for Tooth 22 is visible due to the missing alveolar bone below the erupted tooth. Along with that, there is a possible supernumerary tooth present between Teeth 22 and 23. Due to the positioning of the possible supernumerary tooth and the coloring, it is unclear if it is an actual supernumerary tooth. Also visible is that there was alveolar bone resorption that occurred in the area of the left second premolar.

Another pathology observed was the presence of dental caries and calculus. The types of dental caries that were present were on the occlusal surface (score 1), the interproximal surface (score 2), smooth surfaces (score 3), and large caries (score 6). The amount of calculus found on the indicated teeth were absent (score 0), a small amount (score 1), and moderate amount (score 2) (Brothwell 1981).

Of the bones present in this burial, only two bone could provide measurements. The mastoid length, taken on the right temporal, is recorded as 23.93 millimeters. The following three measurements are from the left mandible: the chin height is 27.70 millimeters, the height of the mandibular body was 36.34 millimeters, and the breadth of the mandibular body is 11.57 millimeter.

As a summary, the individual in Burial 4 in estimated to be an adult over the age of thirty-five years old. Due to the bones that are present, estimations for sex, ancestry, and stature could not be calculated.

Burial 5

The remains found in Burial 5 include a left femur, four metacarpals, and four hand phalanges (Table 16).

Table 16. Bone Inventory for Burial 5

Bone Present	Side	Fragmentation Level	Bone Color[1]
Femur	Left	2 (Proximal Epiphysis and Proximal Third of Diaphysis Missing)	7.5YR 7/2
Metacarpals	Left – 1 Right – 1 Unsided – 2	Left – 1 Right – 1 Unsided – 2	7.5YR 7/3
Hand Phalanges	Unsided – 4	Unsided – 4	7.5YR 7/3

[1] Munsell Color Chart used

Based on the epiphyseal closure and the obliteration of the closure of the distal femur, the age estimation of the individual is adult (Buikstra and Ubelaker 1994, 43). Based on what is present of the femur, there is one measurement possible to record. This measurement is the epicondylar breadth recorded as 72millimeters. The sex estimation was conducted using Spradley and Jantz 2011. Based on the findings, the individual is a female (Table 17).

Table 17. Spradley and Jantz 2011 Sex Estimation for Burial Five

Bone Name	Measure - ment Name	Measure-ment	Female Mean	Female Standard Deviation	Male Mean	Male Standard Deviation	Section-ing Point	Classsifi-cation Rate	Indicated Sex
Femur	Epicond-ylar Breadth	72mm	72.88 mm	3.86mm	83.35 mm	3.97mm	78mm	89%	Female

Based on the findings mentioned earlier, this individual is an adult female. Due to the lack of remains present in this burial, estimation for ancestry and stature were unable to be calculated.

Burial 5a

The remains associated with Burial 5a are one left femur (Table 18).

Table 18. Bone Inventory for Burial 5a

Bone Present	Side	Fragmentation Level	Bone Color[1]
Femur	Left	2 (Distal 1/3 of Diaphysis and Distal Epiphysis Missing)	7.5YR 6/4

[1] Munsell Color Chart used

The left femur #1 provides two measurements. The first measurement is the anterior-posterior subtrochanteric diameter at 30.10 millimeters and the second measurement is the medial-lateral subtrochanteric diameter at 29.89 millimeters. The sex estimation is conducted using Spradley and Jantz 2011. Based on the findings, the individual is a male (Table 19).

Table 19. Spradley and Jantz 2011 Sex Estimation for Burial 5a

Bone Name	Measure-ment Name	Measure-ment	Female Mean	Female Standard Deviation	Male Mean	Male Standard Deviation	Section-ing Point	Classsifi-cation Rate	Indicated Sex
Femur	Anterior-Posterior Subtro-chanteric Diameter	30.10mm	25.86mm	2.65mm	28.73 mm	2.28mm	27mm	83%	Male

The age of the individual is estimated using data derived from Scheuer and Black (2000). Based on the absence of the lesser trochanter on the left femur, the age estimation is that the individual is under the age of seventeen.

In summary, the individual from Burial 5a was a male under the age of seventeen.

Burial 6

The remains found in Burial 6 include an unsided temporal, left and right mandible, right clavicle, left and right glenoid fossa of the scapula, right os coxae, left and right humerus, left and right radius, left and right ulna, left and right femur, left and right tibia, left and right fibula, an unsided talus, one metacarpal, seven hand phalanges, and eight teeth (Table 20).

Table 20. Bone Inventory for Burial 6

Bone Present	Side	Fragmentation Level	Bone Color[1]
Temporal	Unsided	3	7.5YR 5/4
Mandible	Right	3	7.5YR 6/4
Mandible	Left	3	7.5YR 6/4
Clavicle	Right	3	7.5YR 4/4
Glenoid Fossa (Scapula)	Left	3	7.5YR 5/4
Glenoid Fossa (Scapula)	Right	3	7.5YR 6/4
Os Coxae (Whole)	Right	3 (severely fragmented)	-
Humerus	Left	Epiphyses – 3 Diaphysis – 2	7.5YR 5/4
Humerus	Right	3	7.5YR 5/4
Radius	Left	3	7.5YR 6/4
Radius	Right	3	7.5YR 6/4
Ulna	Left	3	7.5YR 5/4
Ulna	Right	3	7.5YR 6/4
Femur	Left	Epiphyses – 3 Diaphysis – 1	7.5YR 6/4
Femur	Right	Epiphyses – 2 Diaphysis – 1	7.5YR 6/4
Tibia	Left	Epiphyses – 3 Diaphysis – 1	7.5YR 6/6
Tibia	Right	Epiphyses – 3 Diaphysis – 1	7.5YR 5/4

Fibula	Left	Epiphyses – 3 Diaphysis – 2	7.5YR 5/4
Fibula	Right	3	7.5YR 5/4
Talus	Unsided	2	7.5YR 6/6
Metacarpals	Unsided – 1	3	
Hand Phalanges	Unsided – 7	3 Phalanges – 1 4 Phalanges – 3	

[1] Munsell Color Chart used

Due to the condition the remains are in, not much information is gathered from them. From a visual analysis, the bones appear to be that of an adult by the size of the bones. Also looking at the size of the bones, they seem to be on the more robust side of the scale, suggesting that these remains would possibly belong to an adult male.

The teeth that were present and identified to the individual in Burial 6 are all permanent teeth that represent moderate wear to them (**Table 21**, **Table 22**). There was some different pathology present on the teeth. Calculus build-up was present on five of the eight teeth ranging in the severity of small amount (score 1) or a moderate amount (score 2) (Brothwell 1981). Tooth #9 was the only tooth that showed signs of hypoplasia. Hypoplasia is found in three locations, all represented by linear horizontal grooves. The positions of the defects were, measuring up from the cemento-enamel junction, at 2.12 millimeter, 3.39 millimeters, and 5.15 millimeters.

Table 21. Tooth Inventory for Burial 6

Tooth Number	Presence	Development	Wear	Calculus
6	1	14	4	0
8	1	14	5	0
9	1	14	4	0
11	1	14	4	1
23	1	14	5	1
24	1	14	5	1
25	1	14	5	2
26	1	14	5	1

Table 22. Dental Measurements for Burial 6

	Maxilla	
Tooth	**I1**	**C1**
Mesiodistal diameter	6.68mm	7.62mm
Buccolingual diameter	7.32mm	7.62mm
Crown Height	10.56mm	7.62mm
	Mandible	
Tooth	**I2**	**I1**
Mesiodistal Diameter	5.06mm	5.55mm
Buccodistal Diameter	5.87mm	6.37mm
Crown Height	6.69mm	6.93mm

Besides the dental measurements, only one other measurement is recorded. The chin height for this individual is 22.29 millimeters.

In summary, based off of visual observations of the bones, due to the size and robustness of the bones, it is estimated that the individual in Burial 6 in an adult male.

Conclusion

The following will provide a summary of the information provided in this chapter. Burial 1/3 is estimated to be an adult male with a stature of roughly 6’1” +/- 3.8”. Burial 2 was also an adult male with an estimated stature of 5’7.65” +/- 1.55”. Burial 4 is estimated to be an adult with no other information estimated. Burial 5 was found to be an adult female. Burial 5a is estimated to be a young adult male (<17 years old). Burial 6 is estimated to be an adult male.

Chapter Seven: Matching of the Dissociated Bones Through Osteological Analyses Methods

Results of the Osteological Analyses

During the analysis of the dissociated bones, findings revealed that there were one hundred-six identifiable fragments and an additional 126 miscellaneous fragments. An age estimation of the identifiable bones indicates they are all adult.

Of the eighteen burials recovered at the Weyerhaeuser site, osteological analyses showed that six of the individuals were adults, three were juveniles/young adults, seven were infants, and two were perinatal (Hogue and Alvey 2006). As only the disturbed burials of the adults are being examined for this research, this includes all five adult burials (Burials 1/3, 2, 4, 5, and 6) and the addition of one young adult burial (Burial 5a).

Due to these results, further analysis of the dissociated bones will be conducted to determine if it is possible to identify which, if any, of the dissociated bones belong to identified adults in the disturbed burials. All single bone elements that were matched to a burial in the Hogue and Alvey report (2005) are being treated as dissociated bones in this research to test the x-ray fluorescence. Table 23 below shows bones found *in situ* in the disturbed burials.

Table 23. Bones Present in Disturbed Burials

Bone	Burial 1/3 Side/Frag	Burial 2 Side/ Frag	Burial 4 Side/Frag	Burial 5 Side/Frag	Burial 5a Side/Frag	Burial 6 Side/Frag
Frontal			Left/2			
Parietal						
Temporal			Right/2 Left/2			Unsided/3
Occipital	Right/3		Right/2 Left/2			
Maxilla						
Mandible			Right/3 Left/2			Right/3 Left/3
Atlas (C1)						
Axis (C2)			**/1			
Cervical Vertebrae (C3-C6)			**/2			
Thoracic Vertebrae						
Lumbar Vertebrae						
Clavicle			Right/2 Left/2			Right/3
Scapula			Left/3			Right/3 Left/3
Humerus			Left/1			Right/3

						Left/3
Radius		Right/1 Left/1				Right/3 Left/3
Ulna		Right/1 Left/1	Left/1			Right/3 Left/3
Carpals		Right (6)*/1 Left (6)*/1				
Meta-carpals		Right (3)*/1 Left (1)*/1 Unsided (1)*/1		Right(1)*/1 Left(1)*/1 Unsided(2)*/2		Unsided(1)*/3
Hand Phalanges		Unsided (26)*/1		Unsided(4)*/4		Unsided(7)*/ 1&3
Ilium		Right/2 Left/1				Right/3
Ischium		Right/2 Left/3				Right/3
Pubis						Right/3
Femur		Right/1 Left/1		Left/2	Left/2	Right/1 Left/1
Patella		Right/1 Left/1				
Tibia	Right/1 Left/1	Right/1 Left/1				Right/3 Left/1
Fibula	Right/1	Right/1				Right/3

	Left/1	Left/1	Left/2
Calcaneus	Right/2 Left/1	Right/1 Left/2	
Talus	Right/2 Left/1	Right/1 Left/1	Unsided/2
Tarsals	Unsided(1)*/1	Right(2)*/1 Left(2)*/1 Unsided(5)*/2	
Meta-tarsals	Right(1)*/1 Left(1)*/1 Unsided(6)*/1	Right(5)*/1 Left(5)*/1	
Foot Phalanges	Left(5)*/1 Unsided(7)*/1	Right(2)*/1 Left(2)*/1 Unsided(15)*/1	

*Number of Bones Present
**Bone Element is not a sided bone

Matching of the Bones

Before using the x-ray fluorescence, an attempt to potentially match the disassociated bones to the potential burial they may belong to was made. To do this, multiple methods were used to help narrow down the possibilities of which dissociated bone belongs to which burial.

Matching Through Bone Color

One method is to use the color of the bones to find any potential matches. The bone color has been recorded for all the identified disassociated bones and all burials that had an adult. The dissociated bones were compared against bone in the same region (cranial, axial, upper body, and lower body) that they belong. This is because throughout a single burial, the different regions have shown to have produced different bone colors.

Cranial Region

Out of the dissociated bones of the cranial region, four of the bones potentially match two burials. The first burial that had potential matches is Burial 1/3. The two dissociated bones from the cranial region are the right temporal #1 and the unsided parietal #3. Both of the dissociated bones have a bone color of 7.5YR 4/4 while the cranial bone present in Burial 1/3, a right occipital, is colored 7.5YR 4/3. While this is not an exact match, they are similar enough to be considered a potential match.

The other burial that was possible matches in this region is Burial 6. The two dissociated bones that may potentially be a match are a possible right parietal #1 and an unsided parietal #2. The bone color of the possibly right parietal #1 is 7.5YR 5/4 and the unsided parietal is 7.5YR 5/3. The cranial bone present in Burial 6 is an unsided temporal colored 7.5YR 5/4. Like with previous burial, the bone coloring of these bones is close enough to be a potential match.

Upper Body Region

The next bone region that has potential matches is the upper body region. This region has eight bones that may belong to three burials. The three burials that have potential bones matches are Burials 2, 4, and 6.

Burial 2 has one bone that may potentially match. This bone is the left humerus #2 that is colored 7.5YR 4/3. Consideration of this bone belonging to this burial is based on the coloring of the radii and ulnas present with the burial. Both the ulnas and the radii produced two different bone colors, which may suggest that the humerus may be one of either coloring. The radii both produced bones colors of 7.5YR 4/4 while the ulnas produced a color of 7.5YR 5/4 and 5/6.

For Burial 4, two bones potentially matched. Two of these bones are left radius #1 colored 5YR 5/4 and right radius #2 colored 5YR 5/4. The two bones that have similar coloring are the left humerus and left ulna from Burial 4. These two bones both have the coloring of 7.5YR 5/4. While the colors are slightly different, when looking at the Munsell Color Chart, the two colors are very close in appearance.

Burial 6 had one bone that is a possible match. This bone is the right scapula #2b colored 7.5YR 5/4. While it is recorded in the burial inventory for Burial 6 that the right scapula is present, the present bone fragment in Burial 6 is only the glenoid fossa of the right scapula. This leaves the rest of the bone to match the burial possibly. The bones that this dissociated bone may match are the right clavicle colored 7.5YR 4/4, the left glenoid fossa colored at 7.5YR

5/4, and the right glenoid fossa colored 7.5YR 5/4. The bones from the burial do represent a variety of different hues, but the hope is that this dissociated bone belongs to this burial.

There were four bones from this body region that have a bone coloring that matches with more than one burial. The first two of these dissociated bones are the right humerus #3 (7.5YR 5/3) and the left humerus #1 (7.5YR 5/4). These bones have similar coloring to bones in Burials 2 and 4. In Burial 2, the bones that were similar to the humerus are the ulnas that are colored 7.5YR 5/4 and 5/6. In Burial 4, the similar bone was the scapula body colored at 7.5YR 5/4.

The remaining two dissociated bones that matched with both Burials 2 and 4 were the right humerus #1a and right humerus #2, both with the bone color of 7.5YR 4/4. In Burial 2, these bones match with the radii that have a color of 7.5YR 4/4. In Burial 4, the dissociated bone has a similar bone coloring as the right clavicle that has a color of 7.5YR 4/3.

While all three of the dissociated humeri indicate that they potentially belong to either Burial 2 or 4, ultimately at least one of the humeri will end up belonging to another burial that is not indicated through bone color.

Lower Body Region

The remaining area that has potential matches based on bone color is the lower body area. This area had two dissociated bones that potentially match any burials. The right ischium

#1 and right talus #1 potentially match either Burial 1/3 or Burial 5a. The ischium has a bone color of 7.5YR 6/3 while the right talus has a bone color of 7.5YR6/4. The bones that the dissociated bones had similar coloring in Burial 1/3 are the left tibia (7.5YR 6/3), the right fibula (7.5YR 6/4), and the left fibula (7.5YR 6/3). In Burial 5a, the left femur had a similar coloring with 7.YR 6/4.

Matching Through Sex Estimation

Another way to help create possible matches before the use of the x-ray fluorescence is to look at the sex estimation for the bones. For reference, Burials 1/3, 2, 5a, and 6 were male, Burial 5 was female, and Burial 4 was of unknown sex.

One of the dissociated bones able to be sexed is the left femur #2. Only one measurement can be gathered from this bone, which can also be used to determine a sex estimation. This measurement is the maximum diameter of the femur head, which measured as 48.52 millimeters. Based on Bass (1995) data for an individual of African ancestry, this bone belongs to a male individual (Bass 1995). Based on this information, the sex matches for Burial 1/3.

Spradley and Jantz (2011) developed a method that uses univariate sectioning points for determining the sex of an African American individual by using a single measurement on a bone. Right humerus #3 was also able to be sexed using Spradley and Jantz (2011) by looking at the minimum and maximum diameter at midshaft. For the minimum diameter of the humerus, females have a mean of 16.03 millimeters with a standard deviation of 1.92 millimeters while males have a mean of 19.48 millimeters with a standard deviation of 1.73 millimeters. The sectioning point for this measurement point is 18 millimeters with a classification rate of 76 percent. The right humerus #3 minimum diameter measured at 18.8 millimeters. For the maximum diameter at midshaft, females have a mean of 20.54 millimeters with a standard deviation of 1.82 millimeters while males have a mean of 23.94 millimeters with a standard deviation of 1.73 millimeters. The sectioning point is 22 millimeters with a classification rate of 74 percent. The right humerus #3 measured at 22.08 millimeters. As indicated by both univariates sectioning points, this bone belongs to a male, which indicates that this bone may belong to Burials 1/3, 2, or 5a (Spradley and Jantz 2011).

Sex estimation is also possible on a couple of other humeri that also have the measurements of minimum and maximum diameter at midshaft. Left humerus #1 has a minimum diameter at midshaft of 20.29 millimeters and a maximum diameter at midshaft of 23.93 millimeters. Both these measurements indicate male suggesting possibly belonging to Burial 1/3, 2, or 5a. Right humerus #1a has a minimum diameter at midshaft of 22.99 millimeters and a maximum diameter of 23.97 millimeters. Like the previous bone, this bone is estimated to be male, thus possibly belonging to Burial 1/3, 2, or 5a (Spradley and Jantz 2011).

The right humerus #1b is another dissociated bone that can undergo sex estimation. The right humerus #1 uses the minimum and maximum diameter at midshaft to determine sex. The measurement of the minimum diameter of midshaft is 20.71 millimeters and a maximum diameter at midshaft is 24.96 millimeters. Both of these measurements indicate that this bone belongs to a male. Additionally, this bone was also complete enough to have the epicondylar breadth recorded. For the humerus epicondylar breadth, females have a mean of 55.28 millimeters with a standard deviation of 2.66 millimeters while males have a mean of 64.14 millimeters with a standard deviation of 3.87 millimeters. For this particular measurement, the authors devised a section point of 60 millimeters, males higher and females lower than 60 millimeters, which has a classification rate of 86 percent. The epicondylar breadth of the right humerus #1 is 62.86 millimeters placing it in the range for male classification (Spradley and Jantz 2011). Based on this information, the sex of the right humerus #1b matches the sex for Burials 1/3, 2, or 5a.

The last bone that was able to be sexed was the left tibia #1. Again using Spradley and Jantz (2011), the point used is the circumference at the nutrient foramen. The female mean is 88.05 millimeters with a standard deviation of 5.92 millimeters while the male mean is 101.38 millimeters with a standard deviation of 8.1 millimeters. The sectioning point is 95 millimeters with a classification rate of 79 percent. The measurement from the tibia is 92 millimeters, which suggests that the bone is female and possibly belongs to Burial 5 (Spradley and Jantz 2011).

Results of the Possible Bone Matching

Through the use of the sexing and matching bone color methods, a number of the dissociated bones are matched to at least one burial. The following bones matched solely to Burial 1/3: right temporal #1 and unsided parietal #3 by color and left femur #2 by sex estimation. Burial 2 had one bone, left humerus #2, that matched just to that burial by color. Two bones, the left radius #1 and right radius #2, match to Burial 4 by color. The left tibia #1 matched to Burial 5 by sex estimation. Burial 6 had the possible right parietal #1, unsided parietal #2, and right scapula #2 that match by color.

Seven dissociated bones had matched to more than one possible burial, yet most of these bones have a burial that is more likely than the other possible burials based on the results of the sex estimations and bone color estimations. The left humerus #1 had matched to Burial 2 or 4 through bone color, but also matched to Burials 1/3, 2, and 5a due to sex estimation. Since Burial 2 is indicated in both methods, it is more likely that this bone possibly comes from this burial.

Both right humerus #1a and #3 both matched to either Burial 2 or 4 by bone color and then matched to Burials 1, 2, and 3 through sex estimation. The right humerus #1b had matched to Burials 1/3, 2, and 3 through sex estimation. The right humerus #2 matched Burials 2 and 4 by bone color. Between these four humeri, it is not clear which burial each of these bones most likely belongs to, but at least four humeri can be matched to the four burials.

Conclusions

Based on the results seen in this section, seventeen bones are either individually or have possibly matched to all six of the disturbed adult burials (**Table 24**). While this may seem like a small portion of identifiable dissociated bones, these seventeen bones will likely be the bones that will be used to help to determine if using x-ray fluorescence is a reliable method to using in bioarchaeology.

Table 24. Bone Matches Through Bone Color and Sex Estimation

Dissociated Bone	Burial 1/3	Burial 2	Burial 4	Burial 5	Burial 5a	Burial 6
Rt. Temporal #1	C					
Unsided Parietal #3	C					
Lt. Femur #2	S					
Lt. Humerus #2		C				
Lt. Radius #1			C			
Rt. Radius #2			C			
Lt. Tibia #1				S		
Rt. Parietal #1						C
Unsided Parietal #2						C
Rt. Scapula #2b						C
Lt. Humerus #1	S	C, S	C		S	
Rt. Humerus #3	S	C, S	C		S	
Rt. Humerus #1a	S	C, S	C		S	
Rt. Humerus #2		C	C			
Rt. Ischium #1	C				C	
Rt. Talus #1	C				C	
Rt. Humerus #1b	S	S			S	

"C" stands for Bone Color
"S" stands for Sex Estimation

Chapter Eight: Use of X-Ray Fluorescence in Matching the Dissociated Bones

This chapter examines the use of x-ray fluorescence on osteological material with two different groups. The first group is the control group that contains two known skeletons. The purpose of this group is to test if the x-ray fluorescence can identify the difference between the two known skeletons. The experimental group is the dissociated bones and the burials from the Weyerhaeuser site. The goal of this group is to attempt to match the dissociated bones to the burials that they belong.

Control Group

The two skeletons used for this group were BSU-SKL-001 and BSU-SKL-002, both belonging to the Ball State University Anthropology Department. As stated before, the purpose of this control group is to determine if the x-ray fluorescence is capable of distinguishing the two individuals from another.

The use of the bones from the skeletons in the control group experiment corresponds with the dissociated bones that were recovered from the Weyerhaeuser site, with the addition that both right and left bone elements will undergo testing. The bones included in this testing include the right and left side of the parietals, temporals, maxilla, mandible, clavicles, scapulae, humeri, ulnas, radii, metacarpals, distal phalanges, innominates, femurs, tibias, tali, and first ribs along with the cervical vertebrae, thoracic vertebrae, and lumbar vertebrae. As mentioned before in Chapter Four, the chemical elements chosen for analysis were calcium, titanium, vanadium, chromium, magnesium, iron, copper, zinc, and potassium.

Table 25. Discriminant Analysis of the Control Skeletons Data

Control Skeleton	Ca	Ti	V	Cr	Mn	Fe	Cu	Zn	K	Prelim-inary Predict-ion	Final Predict-ion	Correct Classificat-ion
1	406216.7	168.3	10.73333	10.36667	538.7	1304.7	14.4	349.3	7509.0	1.423788	1	yes
1	390072.3	161.3	11.06667	13.8	543.3	1111.3	14.4	364.0	6536.0	1.202458	1	yes
1	391306.3	147.3	9.133333	14	469.3	1015.7	18.3	403.0	5985.0	1.275029	1	yes
1	417709.7	134.3	17.4	16.8	262.0	890.0	11.0	290.7	5358.7	1.254371	1	yes
1	349344.7	121.7	13.2	14	382.7	635.7	20.5	218.0	3037.0	1.096427	1	yes
1	377101.3	98.0	7.366667	7.9	292.0	565.7	12.0	208.0	2580.0	1.219538	1	yes
1	450406.3	171.0	14.83333	13.43333	239.7	467.7	8.8	283.3	4860.3	1.421974	1	yes
1	478626.7	128.7	15.66667	16.33333	358.7	607.3	10.2	450.3	3261.0	1.060879	1	yes
1	400650.3	313.7	33.46667	5.3	198.3	349.7	12.0	763.3	1338.7	1.459573	1	yes
1	430645	197.3	12.43333	8	181.3	581.7	10.4	509.0	2068.3	1.224331	1	yes
1	402483.7	1098.3	221.5	26	260.0	897.3	13.5	1618.3	856.7	1.688358	2	no
1	392981.7	328.3	66.2	10	219.7	1167.3	16.0	1650.3	769.7	1.425507	1	yes
1	354451.3	110.0	4.85	0	59.7	396.7	11.5	408.3	1706.3	1.623373	2	no
1	259446	4138.7	983.3	185	172.3	2258.7	27.0	4710.7	2701.0	0.611525	1	yes
1	388756.7	159.3	7.1	7	90.3	215.3	15.0	269.0	2898.3	1.583916	2	no
1	372077.7	213.0	7.033333	5.8	63.7	407.0	11.1	392.0	2729.3	1.421411	1	yes
1	394229	124.3	5.3	0	105.7	350.7	0.0	362.3	2051.0	1.473592	1	yes

1	240685.7	1433.0	300.95	53	73.0	512.7	25.0	2003.7	1457.0	1.545593	2	no
1	446808.7	63.0	3.733333	5	54.7	208.7	0.0	162.7	991.0	1.269036	1	yes
1	465700.7	71.3	7.166667	4.6	124.0	308.0	5.7	239.0	731.3	1.321666	1	yes
1	418687	193.0	6.3	14.8	149.0	837.0	22.8	341.0	1237.0	0.843069	1	yes
1	461643	107.0	7.3	10.5	120.0	654.0	22.0	275.0	1089.0	1.236046	1	yes
1	405484.3	100.7	0	0	109.7	327.7	11.1	227.0	2047.3	1.630198	2	no
1	393550.7	217.3	9.033333	10.7	236.7	1157.3	12.5	448.3	4026.7	1.058587	1	yes
1	414765.3	151.7	6.333333	8.6	90.3	552.7	8.5	936.0	2792.0	1.389372	1	yes
1	420130.3	87.0	5.1	5	72.3	355.0	7.3	434.3	1931.3	1.47379	1	yes
1	389647.7	123.3	6.3	0	121.3	452.0	0.0	181.0	1735.7	1.35444	1	yes
1	452440.7	119.3	7.533333	8.7	119.7	439.7	6.6	381.7	2822.0	1.377852	1	yes
1	457079	38.7	2.95	6.6	54.0	143.7	0.0	179.7	1248.3	1.297941	1	yes
1	457903.3	46.0	2.65	0	54.7	122.0	0.0	144.7	869.7	1.516828	2	no
1	393405	45.7	2.566667	0	81.0	428.7	0.0	311.0	493.3	1.286353	1	yes
1	420176.3	36.7	2.366667	0	85.7	305.0	0.0	275.0	465.0	1.355978	1	yes
1	399413	141.5	6.4	0	148.5	726.0	9.5	175.5	1111.5	1.290688	1	yes
1	397399	162.0	11.8	8.1	234.5	1441.5	13.5	185.0	1621.5	0.784986	1	yes
1	397161	139.5	10.25	0	178.5	1107.0	10.0	190.0	1429.0	1.22548	1	yes
2	415971.3	158.0	3.5	5.8	26.0	1173.0	13.6	383.7	7447	1.964607	2	yes
2	398779.3	159.3	4.15	0	33.7	1233.7	15.3	707.0	7196	2.222004	2	yes
2	400353.3	156.7	4.9	6.3	17.7	1050.0	10.3	381.7	5214	1.609903	2	yes
2	421489.3	144.3	3.033333	0	15.0	1239.3	11.2	364.7	6260	1.991631	2	yes
2	347744.3	126.7	0	0	14.0	427.7	20.0	166.3	3328	1.909841	2	yes
2	316455.3	73.0	0	0	0.0	425.7	14.0	180.3	2008	1.657554	2	yes

2	437431	276.0	3.1	5.2	16.0	666.7	16.0	260.3	5115	1.738946	2	yes
2	430134.3	119.0	2.45	6.05	20.7	958.7	12.6	300.3	5545	1.777375	2	yes
2	418088.7	454.0	5	8	90.0	722.0	9.3	712.7	5324	1.309558	1	no
2	423742.3	283.0	5.133333	6.75	93.7	705.3	11.6	1126.3	5325	1.699612	2	yes
2	384533.7	79.7	4.5	0	62.7	534.3	7.1	410.7	1982	1.594087	2	yes
2	383412.3	103.7	4.75	7.7	54.3	579.3	10.1	350.0	2598	1.356464	1	no
2	324698.3	139.0	0	0	38.0	288.7	11.0	530.3	2968	1.756129	2	yes
2	362529.3	161.0	5.1	0	136.7	387.3	11.5	1225.3	3777	1.961379	2	yes
2	310350	194.3	2.9	0	48.0	285.0	19.7	642.3	3050	1.886296	2	yes
2	159029.7	67.0	0	0	32.0	195.0	34.7	77.3	821	1.750837	2	yes
2	388274	136.3	3.2	5.5	57.0	252.7	15.2	581.3	3398	1.768801	2	yes
2	366267.3	124.3	3.3	0	94.3	268.7	12.3	713.7	3836	2.004736	2	yes
2	458893	65.0	5.033333	5.7	75.7	229.7	7.6	543.3	1109	1.455235	1	no
2	430135	45.0	3.5	0	718.0	250.0	0.0	229.0	763	0.965467	1	no
2	453833	38.0	4.066667	0	71.0	143.0	6.4	472.0	604	1.647686	2	yes
2	450834	39.0	3.7	0	658.0	248.0	6.0	313.0	789	1.164488	1	no
2	382686	176.3	3.233333	0	56.7	867.7	12.3	604.7	4386	1.812224	2	yes
2	403123.7	255.3	3.7	0	55.0	689.0	8.9	418.0	4445	1.726283	2	yes
2	419554	114.0	5.6	8.3	74.0	600.7	10.5	1535.0	3775	1.719948	2	yes
2	373374.3	121.0	0	0	37.0	266.7	11.0	1049.0	2963	1.921325	2	yes
2	365637.3	118.3	5.85	0	66.7	317.3	14.0	176.3	3595	1.947717	2	yes
2	307822.7	122.7	3.8	0	65.5	261.0	25.3	180.0	2743	1.958964	2	yes
2	441024.3	49.7	2.4	0	32.3	126.3	6.3	163.0	1671	1.74114	2	yes
2	433031.3	45.0	2.7	0	36.0	98.7	7.5	150.3	1319	1.716825	2	yes

2	422148.7	52.0	2.566667	0	24.7	323.3	5.6	336.3	1494	1.640671	2	yes
2	428168.7	45.0	2.6	4.9	24.5	192.3	0.0	286.0	1105	1.329894	1	no
2	387747.5	72.0	2.9	0	46.0	625.0	10.0	378.0	1467	1.533917	2	yes
2	413537	90.5	4.7	0	53.5	840.0	15.0	252.5	1529	1.545225	2	yes
2	425633.5	102.0	3.5	0	53.5	784.5	11.0	223.0	1632	1.489281	1	no

BSU-SKL-001=1
BSU-SKL-002 =2

A discriminant analysis was conducted on the data gathered using the data from the elements listed (in **Table 25**). Between the two skeletons analyzed, there were a total of seventy bone elements tested with 81 percent of the bone elements correctly classified to their proper skeleton. While this portion of this experiment did perform well, it leaves that question as to why roughly one-fifth of the bones did not place with their correct skeleton. A few hypotheses that may explain why the results of the x-ray fluorescence analysis of the two control skeletons were produced lower than expected results follow.

The first hypothesis considers the literature (Gonzalez-Rodrigeuz and Fowler 2013; Janos et al. 2011; Perrone et al. 2014), where it is cited that there are different ways that they prepared the bones for testing with x-ray fluorescence. Most of these methods include washing the bones and then letting them air dry. Due to the fragility of the Weyerhaeuser remains and for the sake of consistency of testing between the control and experimental groups, the remains in two groups were not washed in any way. This may mean that any taphonomic or diagenetic change that may have occurred to these remains may have altered the surfaces of the bones over time that would lead them to produce similar results. As much of the origin of the two skeletons is unknown, the type of taphonomic or diagenetic process that the remains may have undergone is unknown.

Another hypothesis is that both skeletons have been used as part of coursework in various courses at Ball State University in the Anthropology Department. In Chapter Four of "Human Remains: Guide for Museums and Academic Institutions," it lists three broad categories that can explain the damage that may have occurred on the bone. These three categories include physical, chemical, and biological. Under the chemical category, it lists hand oils/fingerprints from handling as a possible agent of damage (Cassman and Odegaard 2007). Some of the inorganic materials that have been identified to be found in fingerprint residue are: "chloride, sodium, potassium, ammonia, calcium, sulphide, and magnesium" (Girod, Ramotowski, and Weyermann 2012, 14). Along with other bodily compounds, fingerprints also are capable of leaving other types of contaminations along the lines of food residue, cosmetics, and dust (Girod, Ramotowski, and Weyermann 2012).

An additional hypothesis to consider is if these two individuals had similar cultural or environmental factors. If they experienced similar factors during life, they might have a similar bone composition that might contribute to similar x-ray fluorescence readings.

Experimental Group

The Experimental Group is used to examine if x-ray fluorescence can determine which dissociated bones belong to which of the possible burials from the Weyerhaeuser site. The forty-two dissociated bones and a total of twenty-eight bones from the six burials (nine bones from Burial 1/3, six bones from Burial 2, six bones from Burial 4, three bones from Burial 5, one bone from Burial 5a, and three bones from Burial 6) were tested for this portion of the experiment. The methodology that was used to prepare the data for analysis in the Control Group was implemented again in this section.

Discriminant analyses were run using the calcium, titanium, vanadium, chromium, magnesium, iron, copper, zinc, and potassium data from the bones . A total of six discriminant analyses were run so the dissociated bones could be tested against the burials individually. The data that was used for the analyses is below in Table 26 and Table 27.

Table 26. Burial Data

Burial	Bone	Ca	Ti	V	Cr	Mn	Fe	Cu	Zn	K
1 / 3	Rt Occipital	406629	248	60	57	1690	13097	50	352	557
1 / 3	Lt Tibia	435973	634	159	187	2245	5138	18	316	947
1 / 3	Lt Fibula	288163	227	41	632	934	3336	45	450	522
1 / 3	Rt Tibia	411863	362	53	92	1878	8516	13	470	1113
1 / 3	Rt Fibula	354140	190	20	203	1040	4752	36	368	0
1 / 3	Lt Talus	498606	553	58	45	3466	10643	13	406	772
1 / 3	Rt Talus	426195	1033	74	84	2504	13998	15	488	1275

1 / 3	Lt 1st Metatarsal	464275	634	73	94	2844	8784	20	642	825
1 / 3	Rt 1st Metatarsal	491643	294	67	63	2073	7501	10	427	186
2	Lt Radius	543695	300	91	77	2589	4815	21	320	213
2	Rt Radius	438830	223	58	50	1574	3683	34	282	272
2	Lt Ulna	261795	220	52	87	1231	2545	28	148	629
2	Rt Ulna	425239	425	97	83	2464	4640	20	359	509
2	Lt Metacarpal	570852	573	183	183	2330	7000	20	612	426
2	Rt Metacarpal	585962	381	66	48	3020	7167	18	670	593
4	Rt Clavicle	580123	676	353	368	2097	9672	16	310	368
4	Lt Clavicle	595926	410	96	100	1795	6022	16	337	608
4	Lt Temporal	555119	682	237	379	2264	4318	11	158	881
4	Rt Temporal	579985	363	75	77	2314	8789	16	362	586
4	Lt Frontal	520389	1019	309	378	1410	10094	17	161	1541
4	Rt Frontal	591544	399	180	187	1968	5451	13	346	204
5	Lt Metacarpal	544868	870	423	469	2787	7163	19	362	332
5	Rt Metacarpal	540746	807	468	578	2229	7306	20	496	494
5	Lt Femur	521474	433	275	399	1843	4226	46	230	298
5a	Lt Femur	370850	1725	85	64	3333	8073	23	297	2624
6	Talus	574305	543	196	193	2201	9132	12	176	469
6	Rt? Temporal	612586	345	73	59	2528	7928	10	294	0
6	Metacarpal	606604	470	217	219	2734	6648	18	515	0

Table 27. Dissociated Bone Data

Dissociated Bones	Ca	Ti	V	Cr	Mn	Fe	Cu	Zn	K
CERVICAL VERTE #1	566684	1130	285	294	2023	9364	15	414	1427
THORACIC VERTE #1	352781	3921	153	161	1619	19757	17	270	5353
THORACIC VERTE #2	452464	2083	165	174	1851	13663	17	265	2783
THORACIC VERTE #3	560967	772	58	42	1885	12088	12	269	1096
LUMBAR VERTE #1	410402	2799	147	156	1933	16124	13	264	3632
LUMBAR VERTE #2	569039	951	233	245	2224	9354	15	243	1071
LT RADIUS #1	500653	423	199	230	2464	4869	20	324	414
RT TEMPORAL #1	476746	422	178	168	1417	6335	14	272	352
RT PARIETAL #1	570204	345	117	106	1970	6755	13	238	242
RT ISCHIUM #1	592733	576	105	119	2133	5684	17	445	600
RT SCAPULA #3	499086	414	103	92	2432	9384	18	249	501
UNKNOWN METACAR #1	546400	934	435	461	2739	3501	12	115	874
UNKNOWN METACAR #2	552434	160	39	150	1937	7769	84	1092	0
LT METACARP #1	533715	720	102	92	2444	7129	13	360	661
RT RADIUS #2	570903	789	224	234	2291	6316	17	547	1044
MANDIBLE #1	477652	842	89	84	2437	7860	32	408	1373
PARIETAL #2	583194	542	238	247	2197	5006	11	245	365
MAXILLA #1	502334	519	90	77	3121	9519	37	409	721
LT SCAPULA #1a	529846	308	61	51	2044	5695	25	203	355
RT CLAVICLE #1	564521	579	117	111	2126	7077	12	324	659
RT SCAPULA #2a	552200	311	80	62	1979	7188	13	324	346
ILIUM #1	597722	620	291	300	1511	4719	15	415	378
SCAPULE #3	498090	393	85	75	2544	8773	26	420	466
LT FEMUR #2	579492	605	109	119	1501	5780	14	346	841
RT TALUS #1	581306	941	621	673	1751	7009	19	173	507
RT HUMERUS #1a	368967	375	137	146	1790	3865	33	441	631
LT TIBIA #1	501153	873	193	202	2919	5843	13	233	1140
HUMERUS #3	551009	913	395	402	2006	4780	11	182	837
PARIETAL #3	539987	226	79	67	1717	6728	18	225	0
PHALANGE #1	588300	440	268	284	2016	8384	12	276	0
PHALANGE #2	597973	557	333	375	1886	7996	16	276	0
RIB #1	539373	303	99	95	2046	9037	16	1868	204
RT HUMERUS#2	338295	1317	252	269	2754	6423	23	158	2072
LT ULNA #1	333869	323	152	330	1554	2869	34	535	620
LT SCAPULA #1b	458989	557	82	71	2133	7549	18	463	870
RT SCAPULA #2b	465795	650	86	71	2807	8747	26	425	849

RT HUMERUS #1b	490142	409	123	114	1584	2356	17	328	457
LT HUMERUS #2	520369	582	85	69	2634	4408	18	489	821
LT HUMERUS #1	581704	337	131	199	2156	4722	12	371	312
LT ULNA #2 A	352705	364	68	77	1318	2802	25	204	623
RT HUMERUS #3	569969	380	62	55	1753	4296	12	479	1279
RT ULNA #1	483592	928	101	104	2395	8872	13	425	1139

In Table 28 below, the results of the discriminant analyses of the x-ray fluorescence data are visible. From this process, two bones, thoracic vertebrae #2 and ilium #1, did not match to a single burial. Seven bones did match to single burials. The remaining thirty-three dissociated bones matched multiple burials. In the next chapter, these results are combined with the results from the osteological analyses to determine if any of the dissociated bones can be sorted into a single burial.

Table 28. Burial Matches of the Dissociated Bones

Bone Elements	Burial Matches
CERVICAL VERTE #1	Burial 4
THORACIC VERTE #3	Burial 1/3, 4, 6
RT CLAVICLE #1	Burial 4, 6
LT HUMERUS #1	Burial 4, 5, 6
RT HUMERUS#2	Burial 1/3, 2, 5, 5a
LT ULNA #1	Burial 1,4, 5
THORACIC VERTE #1	Burial 5a
LUMBAR VERTE #1	Burial 5a
MANDIBLE #1	Burial 2, 5a
LT HUMERUS #2	Burial 2, 5a, 6
THORACIC VERTE #2	No Match
RT HUMERUS #1a	Burial 1, 2, 5a
LT ULNA #2	Burial 1, 2
RT ULNA #1	Burial 1/3, 2, 5, 6
RT SCAPULA #2b	Burial 1/3, 2, 5a, 6
LT TIBIA #1	Burial 2, 5, 5a, 6
MAXILLA #1	Burial 1/3, 2, 5a, 6
RT SCAPULA #3	Burial 1/3,4, 6
LT SCAPULA #1b	Burial 1/3, 2
LT RADIUS #1	Burial 2, 5, 5a, 6
RT TEMPORAL #1	Burial 1/3, 2
UNKNOWN METACAR #1	Burial 5, 5a, 6

PARIETAL #2	Burial 5, 6
ILIUM #1	No Match
LT FEMUR #2	Burial 4
HUMERUS #3	Burial 5
LUMBAR VERTE #2	Burial 4, 5, 6
RT ISCHIUM #1	Burial 2, 5a, 6
RT RADIUS #2	Burial 4, 5a
LT SCAPULA #1a	Burial 2, 6
RT SCAPULA #2a	Burial 4, 6
RT TALUS #1	Burial 4, 5
RT HUMERUS #3	Burial 4
PARIETAL #3	Burial 2, 6
RT PARIETAL #1	Burial 4, 6
RT HUMERUS #1b	Burial 2, 5a
RIB #1	Burial 1/3, 2
LT METACARP #1	Burial 2, 5a, 6
SCAPULE #3	Burial 1/3, 2, 5a, 6
PHALANGE #1	Burial 1/3, 4, 5, 6
PHALANGE #2	Burial 4, 5, 6
UNKNOWN METACAR #2	Burial 5

Chapter Nine: Conclusions of Experiments

Conclusions of Burial Matching of Dissociated Bones

When combining the results of the bone color matching, the sex estimation matching, and the x-ray fluorescence matching, the results are interesting. Table 29 below shows the possible burials that each dissociated bones may belong with looking at the bone matching methods of bone color, sex estimation, and the discriminant analysis of the x-ray fluorescence data. A comparison between the possible burial matches and the inventory of the individual burials is the next step. This should help to eliminate any inaccurate matches so the final placement can be made.

The final placement of the dissociated bones occurred in various ways. One way is that the dissociated bone is placed with just the method of x-ray fluorescence analysis. Eight bones were placed to a single burial and thirteen bones matched to multiple burial based soley on the x-ray analysis. The other way that the dissociated bones are placed with the results of the multiple methods. There were ten bones that matched to a single burial and eight bones matched to multiple burials based on the results of the multiple methods implented. Three bones did not have a final placement due to either that no matches were made during the various methods or the skeletons matched already had those bones present. These three bones are the ilium #1, thoracic vertebrae #2, and the right clavicle #1.

Table 29. Deciding the Final Placement of the Dissociated Bones

Dissociated Bone	Bone Color	Sex Estimation	XRF	Skeletal Inventory Comparison	Final Placement
Lt Scapula #1b	NM	NM	B1/3, B2	Go B1/3, B2	B1/3 or B2
Lt Ulna #2	NM	NM	B1/3, B2	Go B1/3 / No Go B2	B1/3
Lt Ulna #1	NM	NM	B1/3, B4, B5	Go B1/3, B4, B5	B1/3, B4, or B5
Parietal #2	B6	NM	B5, B6	Go B5, B6	B6
Ilium #1	NM	NM	NM	NM	NM
Lt Femur #2	NM	B1/3	B4	Go B1/3, B4	B1/3 or B4
Thoracic Vertebrae #3	NM	NM	B1/3, B4, B6	Go B1/3, B4, B6	B1/3, B4, or B6
Thoracic Vertebrae #2	NM	NM	NM	NM	NM
Unknown Metacarpal #1	NM	NM	B5, B5a, B6	Go B5, B5a, B6	B5, B5a, or B6
Lt Radius#1	B4	NM	B2, B5, B5a, B6	Go B4, B5, B5a / No Go B2, B6	B4, B5, or B5a
Rt Temporal #1	B1/3	NM	B1/3, B2	Go 1/3, B2	B1/3
Rt Scapula #3	NM	NM	B1/3, B4, B6	Go B1/3, B4 / No Go B6	B1/3 or B4
Maxilla #1	NM	NM	B1/3, B2, B5a, B6	Go B1/3, B2, B5a, B6	B1/3, B2, B5a, or B6
Lt Tibia #1	NM	B5	B2, B5, B5a, B6	Go B5, B5a / No Go B2, B6	B5
Rt Scapula #2b	B6	NM	B1/3, B2, B5, B6	Go B1/3, B2, B5 / No Go B6	B1/3, B2, B5
Rt Ulna #1	NM	NM	B1/3, B2, B5a, B6	Go B1/3, B5a / No Go B2, B6	B1/3 or B5a
Scapula #3	NM	NM	B1/3, B2, B5a, B6	Go B1/3, B2, B5a, B6	B1/3, B2, B5a, or B6
Lumbar Vertebrae #2	NM	NM	B4, B5, B6	Go B4, B5, B6	B4, B5, or B6
Rt Parietal #1	B6	NM	B4, B6	Go B4, B6	B6
Rt Ischium #1	B1/3, B5a	NM	B2, B5a, B6	Go B1/3, B5a / No Go B2, B6	B5a
Rt Radius #2	B4	NM	B4, B5a	Go B4, B5a	B4
Lt Scapula #1a	NM	NM	B2, B6	Go B2, / No Go B6	B2
Rt Scapula #2a	NM	NM	B4, B6	Go B4 / No Go B6	B4
Rt Talus #1	B1/3, B5a	NM	B4, B5	Go B5, B5a / No Go B1/3, B4	B5 or B5a
Rt Humerus #3	B2, B4	B1/3, B2, B5a	B4	Go B1/3, B2, B4, B5, B5a	B2 or B4
Humerus #3	NM	NM	B5	Go B5	B5
Lt Metacarpal #1	NM	NM	B2, B5a,	Go B2, B5a, B6	B2, B5a, or B6

			B6		
Rib #1	NM	NM	B1/3, B2	Go B1/3, B2	B1/3 or B2
Parietal #3	B1/3	NM	B2, B6	Go B1/3, B2, B6	B1/3, B2, B6
Lt Humerus #1	B2, B4	B1/3, B2, B5a	B4, B5, B6	Go B1/3, B2, B5a / No Go B4, B6	B2
Rt Humerus #1a	B2, B4	B1/3, B2, B5a	B1/3, B2, B5a	Go B1/3, B2, B4, B5a	B2
Unknown Metacarpal #2	NM	NM	B5	Go B5	B5
Phalange #1	NM	NM	B1/3, B4, B5, B6	Go B1/3, B4, B5, B6	B1/3, B4,B5, or B6
Phalange #2	NM	NM	B4, B5, B6	Go B4, B5, B6	B4, B5, or B6
Rt Humerus #1b	NM	B1/3, B2, B5a	B2, B5a	Go B1/3, B2, B5a	B2 or B5a
Rt Humerus #2	B2, B4	NM	B1, B2, B5, B5a	Go B2, B4, B5, B5a	B2
Cervical Vertebrae #1	NM	NM	B4	Go B4	B4
Rt Clavicle #1	NM	NM	B4, B6	No Go B4, B6	NM
Thoracic Vertebrae #1	NM	NM	B5a	Go B5a	B5a
Lumbar Vertebrae #1	NM	NM	B5a	Go B5a	B5a
Mandible #1	NM	NM	B2, B5a	Go B2, B5a	B2 or B5a
Lt Humerus #2	B2	NM	B2, B5a, B6	Go B2, B5a / No Go B6	B2

Key
NM – No Match
B1/3 - Burial 1/3 / B2- Burial 2 / B4 - Burial 4
B5 - Burial 5 / B5a – Burial 5a / B6 - Burial 6
Skeletal Inventory Coding - Go = bone element not in inventory /
No Go =bone element in inventory

Final Experiment Conclusions

Overall, there are a few conclusions that are drawn from this research. With the control group experiment, the discriminant analysis of the x-ray fluorescence data was able to correctly identify 81 percent of the bone elements to the correct skeletons. Each skeleton had thirty-five bone elements tested; Control 1 had twenty-nine bone elements and Control 2 had twenty-eight bone elements correctly identified. In the case for the control group, the x-ray fluorescence performed very well and that unknown other factors, such as fingerprint residue, soil/water contaminations, or similar lifetime factors, may have led to the misclassification of some bones.

Examining the results from the experimental group experiment, the reliability of the results that the discriminant analysis of the x-ray fluorescence produced is reasonably sound. From the results in Chapter Eight, all, but two, of the dissociated bones were tentatively matched to at least one burial. After the final placement, eight bones placed to a single burial based solely on the x-ray fluorescence data while ten bones matched to a single burial based on the results of the various methods employed. Three bones could not be matched to any burial. The remaining twenty-one bones matched to multiple burials, thirteen bones based on x-ray fluorescence data and eight bones based on the mixed methods results, and could not be placed to a single burial. Overall, about 43 percent of the bones were able to be placed to a single burial while 50 percent of the bones were placed to multiple burials and the last 7 percent were not matched to any burial (Table 30).

There is one issue with the results of the dissociated bone placement. Burial 2 had two right humeri and two left humeri match, which means that at least two of these bones do not belong to that burial and that muddles overall placement rate by roughly 5 percent.

Table 30. Final Placement of Dissociated Bones from the Weyerhaeuser Site

Burial 1/3

Left Ulna #2	Right Temporal #1			

Burial 2

Right Humerus #1a	Right Humerus #2	Left Humerus #1	Left Humerus #2	Left Scapula #1a

Burial 4

Right Radius #2	Right Scapula #2a	Cervical Vertebrae #1		

Burial 5

Left Tibia #1	Humerus #3	Unknown Metacarpal #2		

Burial 5a

Right Ischium #1	Lumbar Vertebrae #1	Thoracic Vertebrae #1		

Burial 6

Right Parietal #1	Parietal #2			

Matched Multiple Burials

Left Scapula #1b	Left Ulna #1	Left Femur #2	Thoracic Vertebrae #3	Unknown Metacarpal #1
Lumbar Vertebrae #2	Right Talus #1	Left Metacarpal #1	Rib #1	Phalange #1
Phalange #2	Left Radius #1	Right Scapula #3	Maxilla #1	Right Ulna #1
Scapula #3	Mandible #1	Right Humerus #3	Parietal #3	Right Humerus #1b

Right Scapula #2b

Unmatched Bones		
Ilium #1	Thoracic Vertebrae #2	Right Clavicle #1

Future Studies

By examining the results of both the control and experimental groups against the results seen in the literature review, washing the bones may be an important step to take when possible. While the current state of the Weyerhaeuser remains dissuades additional cleaning for preservation sake, an experiment that could be conducted in the future is first to wash the control group with deionized water and test them again with the x-ray fluorescence then compare the results against the “unwashed” results. This would provide greater insight into whether washing skeletal remains is necessary for more accurate results.

Another future unrelated research project that would be interesting to pursue is a replica of Nganvongpanit et al. (2016a) experiment with North American humans and faunal remains (discussed in Chapter Three: Review of X-Ray Fluorescence and Commingled Human Remains). This research could be extremely beneficial archaeological work, especially in the instances where there may be a question if human or faunal remains had been found or if there is a project that is zooarchaeologically based.

Appendix 1

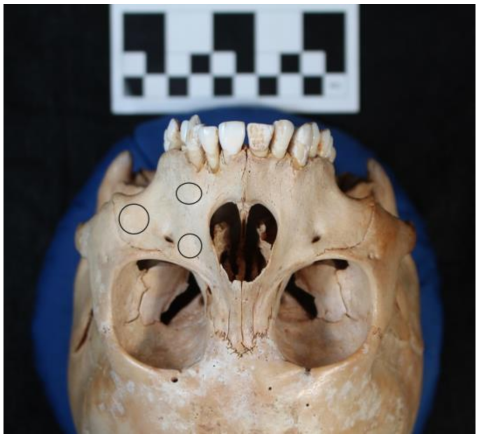
This appendix contains the photographs of the dissociated bones from the Weyerhaeuser site and Control Skeleton #1. These photographs show the points where the x-ray fluorescence data was gathered.

Control Skeleton #1

Photographs of Control Skeleton #1 represent the points that were used for the x-ray fluorescence on both this skeleton and Control Skeleton #2. All photographs in this section are from the left side of the skeleton.

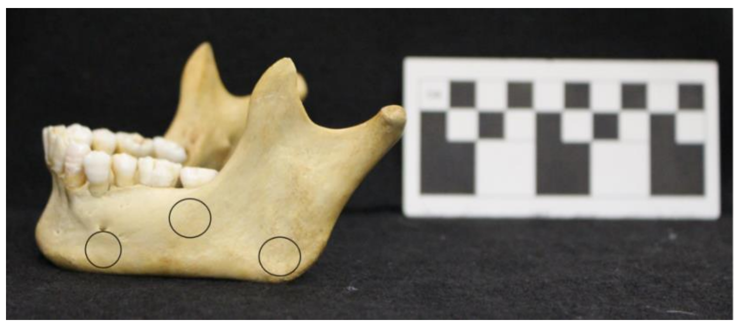
Parietal - Bregma, Midbone, Occipital Angle

Temporal – Squama, Supramastiod Crest, Mastiod



Maxilla – Infraorbital Foramen, Zygomatic Process, Canine Jugum

Mandible – Gonial Angle, Oblique Line, Mental Foramen



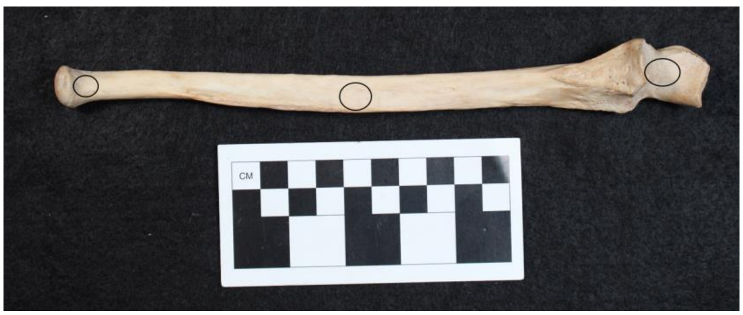
Scapula – Inferior Angle, Scapular Spine, Scapular Neck

Clavicle – Sternal End, MidBone, Acromial End

First Rib – Rib Head, MidBone, Sternal End

Humerus – Neck, Midshaft, Coronoid Fossa

Radius – Head, Midshaft, Anterior Surface



Ulna – Guiding Ridge, Midshaft, Ulnar Hear

Distal Phalanx - Midpoint

Metacarpal – Head, Midbone, Distal End

Innominate – Greater Sciatic Notch, Ischial Body, Iliac Body (Not Shown)

Tibia- Tibial Tuberosity, Midshaft, Distal End

Femur – Below Gr
Trochanter, Midshaft
Pallelar Surfac

Cervical Vertebrae – Superior Body Surface an Inferior Body Surface

Talus – Trochlea, Anterior Subtalar Facet, Superior Subtalar Facet

Thoracic Vertebrae – Superior Body Surface and Inferior Body Surface

Lumbar Vertebrae - Superior Body Surface and Inferior Body Surface

Dissociated Bones from the Weyerhaeuser Site

The bones photographed in this section are the dissociated bones from the Weyerhaeuser Site. Unlike with the bones from Control Skeleton #1, the points on these bones will not have the points labeled due to the points usually not occurring near identifiable landmarks.

Right Parietal #1

Unsided Parietal #2

Unsided Parietal #3

Right Temporal #1

Left Maxilla #1

Left Mandible #1

Left Scapula #1a

Left Scapula #1b

Right Scapula #2a

Right Scapula #2b

Right Scapula #3

Unsided Scapula #3

Right Humerus #1a

Right Humerus #1b

Right Humerus #2

Right Humerus #3

Right Clavicle #1

Unsided Humerus #3

Left Humerus #2

Left Humerus #1

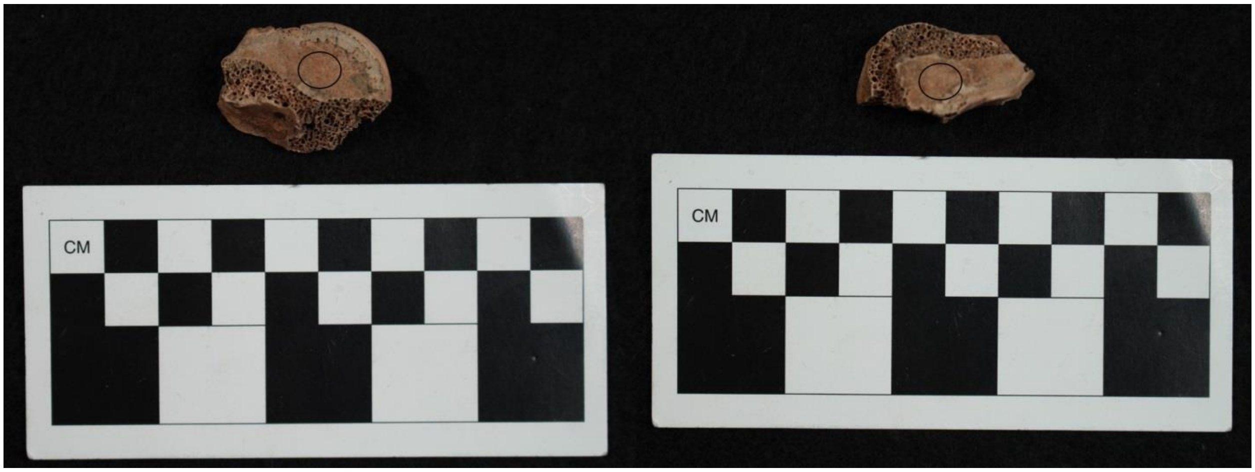
Left Radius #1

Right Radius #2

Left Ulna #1

Left Ulna #2

Right Ulna #1

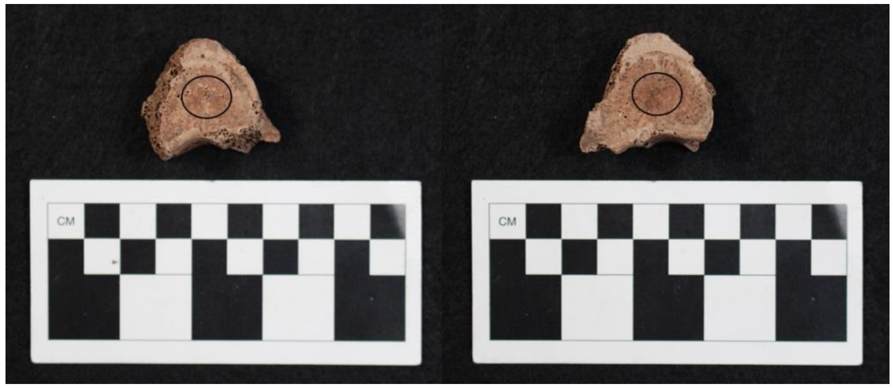


Cervical Vertebrae #1
(Superior and Inferior Views Shown)

Thoracic Ve
(Superior and Infe

Thoracic Vertebrae #2
(Superior and Inferior Views Shown)

Thoracic Vertebrae #3
(Superior and Inferior Views Shown)



Lumbar Vertebrae #1
(Superior and Inferior Views Shown)

Lumbar Vertebrae #1
(Superior and Inferior Views Shown)

Rib #1

Unknown Metacarpal #1

Unknown Metacarpal #2

Left 3rd Metacarpal #1

Unknown Phalange #1

Unknown Phalange #2

Right Ischium #1

Right Ilium #1

Left Femur #2

Right Talus #1

Left Tibia #1

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